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SYNERGY, INTELLIGIBILITY AND REVELATION IN NEIGHBOURHOOD PLACES

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To Ruth, Barnaby and Amelia.

With thanks to Alasdair,
the Garden Girls (Melisa, Magda, and Anta),
and my own friendly pedant Deirdre Ruane.

Abstract

In architectural and urban design the notion of place is highly desired, or in its absence, strongly criticised. Yet what is place and how might it be engendered by design? Over the last 30 years an extensive body of research on place has emerged, largely based on phenomenological approaches. This work gives rise to the question of whether place is a purely social concept completely divorced from physical space, or is linked to space and therefore amenable to design based intervention. Talen and Relph, for example, assert that there is no link between space and the social notion of place. This thesis attempts to approach place from a highly empirical and positivist methodology grounded in the theories known as space syntax but inspired by phenomenological approaches to place. The hypothesis presented here is that neighbourhood-place, or sense of the genius loci of a place, is partially dependent on the global homogeneity of the relationships between spaces defining a region (the neighbourhood) combined with a local heterogeneity of the spatial properties that create a place's identity. Results from a study show that a measure of total revelation (a measure of the difference in information content between a space and its immediately adjacent spaces) is consistent with the degree to which participants would locate a café/place, reinforcing other work done in the area and by environmental psychologists such as Kaplan and Kaplan. Total revelation serves as a powerful measure of the local heterogeneity of a location and hence a place's identity. In further experiments presented in this thesis, neighbourhood boundaries were compared to the areas reported by inhabitants and against new measures of point synergy and point intelligibility, as well as a number of methods suggested by Raford and Hillier, Read, Yang and Hillier, and Peponis, along with a 'null' control measure. Evidence is presented suggesting that point synergy is the most effective method for predicting a neighbourhood's extent from its spatial configuration, hence making it a suitable method to define the global homogeneity of a named district. This work concludes by suggesting that that while place may be unrelated to geographic location there is evidence to suggest that it is related to space (in the configurational or architectural sense) which would appear to contradict those who assert that the notion of place is wholly unrelated to the physical aspects of space. From an architectural perspective this thesis suggests that certain key aspects of spatial design are present in the affordance of social neighbourhoods.

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Chapter 1: Introduction

Summary

This chapter introduces the context and core argument for the thesis. The background for this thesis is grounded in criticism of many developments in urbanisation as lacking in a sense of place or being "place-less". This raises a question about the definition of place, which is a question that has been approached in an extensive body of literature in humanistic geography. The study of place is largely a phenomenological one, which begins with the separation of the physicality of a geographical space[1] and the individual's response to place. There is considerable debate in the literature about the role of space[2] in relation to place. Yet, it can be argued, if place is to be designed, it needs to be amenable in relation to the kinds of physical aspects of the environment that designers can influence. This thesis goes on to evaluate space (in the architectural sense) and its configuration as a possible and underexamined means by which place may be afforded (but not determined). Work such as that of Norberg-Schulz suggests that 'place' is the character or spirit of a location and as such can be 'read' from the environment around us. It is therefore suggested that a neighbourhood-place has two fundamental aspects, a global homogenous texture holding a local heterogeneous mechanism for character/identity/genius loci. The thesis goes on to suggest, based on the work of Hillier, that a neighbourhood is related to the intelligibility of an area or to the relationship between the local and global structures, called synergy. It goes on to propose, from the work of Franz and Wiener on embodiment, that their definition of a spatial measure called 'revelation' may be one candidate for that local heterogeneous measure. The thesis then reports on two experiments. The first suggests that revelation is a measure of an aspect of place that people are sensitive to when looking for the location of place embodied in the idea of a café. The second experiment tested new measures of the structure of urban configuration, point synergy, point intelligibility and others from the literature as a predictor of the impressions of inhabitants about their local neighbourhood. Statistical tests were applied that suggest that point synergy is the best predictor of the responses. The thesis concludes by suggesting that while place may be unrelated to location it does appear that space in the architectural sense can afford the potential for place at the level of the neighbourhood.

Introduction

It seems reasonable for a thesis on the built environment to begin with a definition of the

1. Location is frequently referred to as space in the humanistic literature.
2. Most texts on the matter discuss space and place but, as is shown in the chapter, there is a conflict in the use of the term space. For this thesis, location is substituted for place in reference to phenomenological texts to fully clarify the distinction for an architectural audience.

purpose of research on built environments, such as ‘an attempt to improve the quality of our lived environment’ (CABE 2004). In 1900, only 14% of humanity lived in cities. By the century’s close, 47% of us did. In 1950, there were 83 cities in the world with populations exceeding one million; but by 2000, this number had risen to 411. Over the last century, we have seen a massive increase in urbanisation, with the result that close to 50% of the population now live in cities (Fund 2007). Because of this, the design of the built environment is becoming more important to a larger segment of the population. While the need for shelter is increasing, there has been a growing criticism of the kinds of places that are being built. Architectural critic Nairn (Nairn 1957) for example created the term “Subtopia” to refer to places that failed to have a character or spirit of place. This is echoed by the work of French anthropologist Augé (Augé 1995) who created the term ‘non-place’ to describe locations ranging from motorways/highways to airports and supermarkets. The term non-place also mirrors human geographer Relph’s term ‘placelessness’ (Relph 1976a) for a location lacking individual character.

Over the past century this criticism has not been restricted to a few. Jane Jacobs (Jacobs 1961), Kunstler (Kunstler 1993) Tzonis (Leafier and Tzonis 2003), Frampton (Frampton 1985), Rae (Rae 2003), Tuan (Tuan 1990) and Relph (Relph 1976) have criticised much modern development as ‘subtopia’, ’sprawl’ and critically ‘placeless’. This criticism has not only come from outside the architectural profession; groups such as New Urbanism (Katz 1994) (in the US), the Urban Village movement (Aldous et al. 1992) (in the UK), Cittaslow (the slow cities movement) in Europe (Pink 2007) and Critical Regionalism (Frampton 1985) from within the architecture and planning fields are attempting to respond to these perceived deficiencies by creating not just buildings but places.

These attempts to create amenable places, sometimes with overtones of arcadia and a return to the kinds of social communities of our past, are by no means modern phenomena. In the 1920s Perry’s urban unit was an attempt to meld modernity (which at that point was late Edwardian) with social objectives designed to foster a sense of community. This work was duplicated in the 1950s when Stein and Mumford (Stein and Mumford 1966) attempted to create a healthy liveable community. Yet it is just this kind of work that appears to be at the root of what would now be thought of as Sprawl. Given the history, it would be reasonable to feel that if place or neighbourhood was simple to engender, we should be able to do it by now. Given the contemporary desire for place as expressed by the New Urbanist movement, and the historic failure to deliver it, it seems like an opportune moment to step back and look at what place might be, and suppose that perhaps place might not be as formulaic as previous thinkers might have assumed.

This generates the question: what is ‘place’? Can place be ‘made’ or designed for in the architectural sense, or is it a purely sociological concept divisible from what is the built environment, or is the relationship between built form and place more complex and subtle?

As we will see in the literature review in Chapter **2**, over the years, the notion of place has been a question for both the built environment field and its companion disciplines, such as human geography. One approach that lies strongly and temptingly in the realm of human geography to place is that of phenomenology. Place in the geographic sense can be summarised as the emotional connection between a person and location, a concept embedded in humanistic geographer Yi-Fu Tuan's (Tuan 1974) term 'topophilia' – the love of place. This concept of place as an emotional attachment resonates strongly with the terms for the quality of a lived environment. Clearly, the concept of place in human geography extends well beyond that which might fit well with a built environment. For example, the kinds of emotional attachments to their country that would make people willing to fight for it sits well with topophilia but less well with the kinds of understanding needed to refine the arts of constructing the built environment.

Despite approximately thirty years of scholarly research into the value of place to concepts like identity, there is no clear consensus on how place may be fabricated. This is not intended as a criticism of the phenomenological approach from a psychological perspective the phenomenological approach to place is affective, concerned with the emotional attachment to place. What it does is present that the idea of place is a real one. The work of space syntax in this psychological perspective is partly about cognition - how we understand and make sense of place; and partly behavioural - how place motivates and affects behaviour.

It is the purpose of this thesis to begin to answer the question of the fabrication of place, and to develop tools and theories to understand place. Yet before we can be brought to the core question the notion of the deliberate fabrication of place must be slightly unpicked. Clearly there is no need to understand or have a theory of place to create one. Vernacular settlements have been built which have a strong sense of place. Those constructing these settlements had no explicit theory of what place was but managed to create one nonetheless. Yet despite the sincerity of the New Urbanist movement can any of their developments be said to have created neighbourhoods? Or rather is the ability of New Urbanism better at creating neighbourhoods to typical sprawl development? Perhaps the failure of some New Urbanist settlements is not due to having a theory but having the wrong theory. The objective of this research is to see if by using some of the insights of the phenomenological approach to place, it is possible to create an objective empirical theory that is correct enough to understand those design decisions that will impact on the formation of a sense of place at the neighbourhood level.

In attempting to look for theories that can be empirically attached to place this thesis is attaching itself to a debate instigated by the geographer Yi-Fu Tuan (Tuan 2001) about the distinction between place and location. This debate has also been expressed in other disciplines, such as urban planning, witnessed by the critique of new urbanism by Talen (Talen 1999a), where she states that there is no evidence to support New Urbanist claims about the link between physical form and a 'sense of community' (or a sense of place). This thesis then becomes partly the search for objective evidence to create an association between a built object and the formation of a 'neighbourhood-place'. Place is a rich and wide-ranging concept that embraces everything from nations to favourite chairs. This thesis seeks to simplify the issue by only making claims about neighbourhood places rather than the entire gamut of place. This thesis uses the term neighbourhood place to refer to a neighbourhood-centric notion of place. It is from New Urbanism literature that terms like 'sense of community' are used to refer to the neighbourhood as place, that is while the concept of community can be trans-spatial, the use in that literature assumes spatial locality.

In Chapter 2 one important problem introduced by the literature of human geography using the phenomenological approach typified by Tuan compared to that in the architectural realm is the terminology of space and place. It will be pointed out that space used by Tuan based in geographic terms refers to the more mathematical usage, what architects might refer to as location. The chapter will go on to define the terms used in this thesis, with space meaning the more architectural sense of the term (the inhabitable void defined by forms) and the term location is used to replace space in the geographic sense. With place referring to that more social notion of place more particularly associated with the neighbourhood place.

The basis of this thesis is that little objective research has been undertaken into the understanding of place. While there is a rich and substantial body of literature on place, this study approaches the subject from the position of finding the meaning, implications and consequences of place rather than understanding place in the world and how it might be created by design.

While the concept of geographic place becomes an important framework for research, the practice of creating a sense of place, as we will see in the literature review, moves on to architectural and from planning theorists such as Lynch and Hillier. We will see that architectural theorist Hillier (Hillier and Hanson 1984) introduces a highly objective empirical approach to understanding known as 'Space syntax'. The thesis itself is strongly based on this objective, empirically-based theory and is grounded on the observations made by **Hillier in the late 1990s** on 'well formed neighbourhoods'. It will be argued in chapter 2 that space syntax has not made significant empirical inroads into place as described by many phenomenologists.

As we will see in the literature review, a number of authorities, such as the architectural phenomenologist Seamon (Seamon 2004) and Hillier (**Hillier**), promote the benefit from further dialogue between the two distinctive fields. The literature review continues to look at some previous approaches in the field of space syntax to use space to understand neighbourhood. It was found during this review that while previous syntactical research has looked at place as represented by neighbourhoods, no previous approach has produced strong empirical evidence to support the assertion that appears to match theory with reality.

As we shall see in the third chapter – the **problem definition** – this thesis has become rooted in the work of Norberg-Schulz (Norberg-Schulz 1976), an architectural theorist strongly influenced by the work of Heidegger. While it becomes clear that there are phenomenological paths to the concept of place, it is equally unclear whether there are routes from these reflections to processes to create or design 'place'.

The chapter observes that some of the reasoning by the philosopher Susan Langer suggesting that there is no link between location and place does not apply if we think of space and place. The chapter returns to the notion of place having a constant 'character', as Norberg-Schulz (Norberg-Schulz 1971; Norberg-Schulz 1976) put it. From this it derives some fundamental observations about place.

Homogeneity: The first is that a place must have some continuity of character that would lead one to associate a set of locations (or a space) together as one 'place'.

Heterogeneity: The second is that we must experience some local variation of that continuity to give the place the kind of character that differentiates one place from another.

While it is not the intent to claim that space alone is the totality of urban texture and variation, it is a largely neglected area that deserves work and is distinctive from previous more pattern-based approaches typified in new urbanism.

The third chapter ends with the contention that the fusion of intelligibility/synergy and revelation as the global and local aspects of space as the components of place are fixed in the place hypothesis. Neighbourhood-place is an expression of global continuity and the unique identity of spaces, while simultaneously being matched by an absence of local continuity in the spatial visual field, such as measured by revelation.

This becomes the problem definition for the thesis – can the concept of neighbourhood have any root in the space? Or, is neighbourhood completely disassociated from space? Secondly, can the concept of space provide enough local variation to give space character, i.e., turn space into the basis for place?

Chapter four, the introduction to space syntax theory, pauses from the main argument to introduce the reader to the relevant theories of space syntax used in this thesis. Although this may be skipped by those familiar with space syntax techniques, this chapter does introduce some lesser-known aspects of space syntax theory, such as intelligibility, synergy, revelation and vicinity, which are built upon in the chapters that follow. It should be noted for the knowledgeable reader that angularity, for several reasons which will be made clear in that chapter, is deliberately not used in this thesis.

In chapter five, the theory of revelation, the measurement of revelation is reviewed. Revelation is a measure of space derived from Michael Benedikt's (Benedikt 1979) isovist and developed by Franz and Wiener (Franz and Wiener 2005), which is intended to measure how much change in the space around a point is caused by a small movement in position. After operationalising it in the context of a gridded isovist, a variant s-revelation is introduced which normalises revelation by the connectivity of the grid cell. This is followed by the development of a new space gradient visualisation based on Benedikt's notion of 'new space'. This chapter also introduces an axial implementation of revelation that can be used at the urban level based on the change in axial length when passing from one axial line to another. It then shows that for a number of axial maps, axial revelation correlates with the isovist revelation used in the chapter. Following that, we turn our attention to an evaluation of revelation.

Given the development of revelation, we are then free to move on to the study of place under controlled conditions. **Chapter six**, Revelation in Specific Environments, presents an online experimental technique derived from the work of Brettel (Brettel 2006), along with the results of the experiment. The work shows that a space with a larger absolute change in isovist area is favoured by participants as 'more place-like', thus providing evidence in the spatial realm that backs up the general findings for more visual stimuli from authorities such as Kaplan and Kaplan (Kaplan 1988). This is presented as evidence in favour of the second part of the place hypothesis – that local variation in space makes a location more placelike.

Chapter seven introduces the test areas used to identify neighbourhoods and shows that, in the comparative case of London, the axial revelation of an area suggests that there is a difference between urban and sub-urban conditions. Note the areas used are introduced later in chapter nine.

Chapter eight, the theory of point intelligibility and point synergy mapping, introduces point intelligibility and point synergy mapping --by looking in detail at the basis for neighbourhood described by Hillier (Hillier 1996). After establishing that intelligibility is partly, as one would expect, a product of size, we see through the process of creating an intelligibility profile that the remaining scale (size) free component is left as an independent measure of configuration complexity. This leaves the way free to create a new and surprising measure of space through the novel process of point intelligibility and point synergy mapping. Having established that these effects are not the inevitable product of graphs constructed from axial lines, we are left to see them as products of the urban configuration. What is surprising is that neither point intelligibility or point synergy appear to map movements through space, as integration and segregation do, but rather the continuity of the values appears to correlate with our intuitions about the neighbourhoods of an area. Thus, areas with a continuous colour (value) appear on maps to identify the spatial basis for a neighbourhood.

In **chapter nine, assessing homogenous spatial areas**, we shift our focus from theoretical construction to the empirical testing of these new measures, bringing in a number of methods to do so. Looking at the neighbourhood data reported by Lynch (Lynch 1960) on an area of 1960s Boston known as Beacon Hill, we find that by changing a point synergy parameter we are able to identify not only the broader area but also the more local unofficial sub-neighbourhoods called the front and back sides. Not being satisfied with working with Lynch's data, a number of case studies are presented where techniques are partially derived from Lynch's neighbourhood survey technique and then developed into a new, larger postal survey methodology. With this methodology, we see that while neighbourhood is not a trivial concept, it does have regularities and these regularities appear to be consistent with the neighbourhood mapping techniques developed in chapter seven. The chapter continues by developing methods to construct a single 'consensus boundary', a single average boundary for the returned survey data. The chapter goes on to introduce a method to test the boundary against that derived from the point intelligibility and point synergy mapping methods. The conclusion is that the reported bounds are consistent with the assertion that these are non-random overlaps. The chapter then introduces a second technique that tests how well a method predicts the consensus boundary.

Chapter ten then takes the empirical data collection methods presented in chapter nine and applies them to a number of test areas: Hampstead Garden Suburb, Brentham Garden Suburb and Clerkenwell. A test is then applied that compares previously published methods, one axial version of a segmental method (Embeddedness) (Yang and Hillier), Read's average integration, Raford's axial orientation method and a null test on each area. The chapter concludes that the point synergy method typically outperforms the previous methods and performs significantly better than the null test.

In **chapter eleven**, the thesis is concluded with the threads of evidence brought together to substantiate, as much as possible, the claim for the place hypothesis. Future work to further substantiate the place hypothesis is discussed along with potential implications for the subjects touched. This work helps to independently verify the claims of Hillier and Yang (Yang and Hillier) (Hillier et al. 2007) about the potential for mechanisms by which space can be used to find neighbourhood. If extensively substantiated, this could have a number of consequences in a range of debates in the fields of architecture, planning, urban design and landscape planning. For example, one planning theorist, Talen, has suggested 'that planners need to detach themselves from the idea that physical planning can create a "sense of community"' (Talen 1999b) and by implication a sense of neighbourhood or sense of place. Such suggestions might have to be revised in the light of the theory and empirical data presented in this thesis, together with other work presented in the field. The chapter concludes by focusing in on the power and implications of the point synergy mapping methods and the role of space in the affordance of 'natural neighbourhoods'.

Chapter twelve then explicitly identifies contributions made by this thesis through practice and knowledge, then goes on to Finally, further research and extensions to the methods found in the thesis are discussed.

Key points

It is reported that the world's population is very close to being more urban than rural. This has created a situation where urban design affects the majority of humanity.

Much of the development of the last century has been critiqued as 'placeless'.

While there has been extensive writing on the essence of place, there is little objective information about how to 'design' place.

This thesis seeks to explore place from a more objective empirical position compared to the phenomenological methodology commonly used in geography.

The rest of the thesis can be outlined as follows.

- Chapter two reviews the literature on place and shows that the separation of place and location (place and space) is still a subject of debate.
- Chapter three gives the problem definition and introduces the place hypothesis – that place depends, at the most fundamental level, on heterogeneity and homogeneity at different scales. This thesis seeks to explore a purely spatial approach to this in the context of neighbourhood place.
- Chapter four introduces the core space syntax relevant to this thesis.
- Chapter five expands on the theory of the isovist to introduce revelation or

new space as a measure of spatial interestingness.

- Chapter six tests revelation using an online experiment. This and the body of previous work appear to confirm that participants are sensitive to space when choosing a place.
- Chapter seven begins with the homogeneity part of the place requirement, discusses the inherent properties of intelligibility and synergy and introduces the new method of point intelligibility mapping and point synergy mapping. It is observed that this mapping appears to identify neighbourhoods.
- Chapter eight introduces various tests for the neighbourhood finding mechanism using a set of reported neighbourhoods collected from local inhabitants of a number of areas in London. New comparative methods are developed to assess the results and it is shown that the results are both nonrandom and better than all comparable axial techniques.
- Chapter nine applies axial revelation to the test areas and finds that there is a change of 'character' that can be measured between urban and suburban locations.
- Chapter 10 reviews the theory and evidence and concludes that while it may be correct to assert that there is no connection between location and place (in the social sense), there is now strong evidence for place being embedded in space (in the architectural sense).

Chapter 2:
Literature Review

Chapter Summary

The literature review begins with the observation that a number of authorities in various fields have critiqued much of new urban development as placeless, or without a 'sense of place'. The notion of place has a rich and prolific literature in the field of humanistic geography. Central to these notions is the separation of the idea of geographic location (called space in that literature) from the notion of place, which is regarded as a more emotional and social condition. While the separation of location and place is a useful interpretive distinction, it has been criticised by philosophers such as Lefebvre. Yet for others, such as Susan Langer, it is self-evident that there is no linkage between a physical location and the cultural phenomenon of place. For architects, this leads to the difficult problem of trying to design for place. This chapter goes on to suggest that this is made more difficult when trying to interpret the literature due to the differing conceptions of 'space'. As will be seen, much of the writing on place regards space in the geographic and mathematical sense of the term rather than the architectural notion of space as the thing that lies between and is defined by tangible forms. For clarity, this thesis will use the term space in the architectural sense and location as a substitute for the largely mathematical/geographic use of space. The thesis refers to the architect Norberg-Schulz, who introduced to the theory of place the concept of space as the genius loci, the spirit or character of a region. This notion of place as being embedded in the character of a place is further taken up by the planning theorist Lynch as that which is received when one has a 'sense of place'. The chapter goes on to identify the notion of space that is extensively used by the architectural theorist Hillier as an interesting intermediary between place and location. It then observes that a number of voices, both from architectural theory and phenomenology, have identified the extension of space syntax theory grounded in phenomenological visions of place. The chapter ends with a review of some previous work on neighbourhoods or sub-areas in cities and identifies them as neither being centrally focused on place nor having strong empirical data showing their basis in reality.

Introduction

The political scientist Rae (Rae 2003a) used New Haven, Connecticut as a case study to demonstrate how, beginning in the 1870s, traditional American urbanism began to be overwhelmed by a number of forces that eliminated local street life by the 1920s. The list of detractors to the growth of the modern city would not be complete without reference to Jacobs (Jacobs 1961), who eloquently fought against what she saw as the death of the American city. These criticisms are not restricted to those outside architecture. Critical regionalism, a term first used by Lefaivre and Tzonis and articulated in 'Towards a Critical Regionalism: Six points for an architecture of resistance' by Frampton, shows that architects are also uncomfortable with the apparent placelessness of modern architecture.

This apparent decline in the ability to produce places rather than just shelter has been in many ways matched by architects and planners who have taken these challenges and attempted to produce new solutions. The New Urbanism (Leccese, Arendt, and McCormick 2000) (Katz 1994) movement is just the current generation of those attempting to create places rather than placeless housing. Political scientist Rae's book 'City: Urbanism and its End' (Rae 2003b) argues that the most important modern endeavour is "New Urbanism", the attempt to reintroduce the qualities of the traditional city into contemporary design practice. Yet, as Seamon points out, the old urbanism that Rae praises in his book "just happened — it unfolded for the most part spontaneously because of a particular constellation of historical, technological, and economic circumstances" (Seamon). While few would argue against the ideals of New Urbanism, it has already been criticised by Talen (Talen 1999), who suggests that the design principles of New Urbanism have no basis in empirical evidence. It would be unfair to single out New Urbanism from this point of view. Christopher Alexander (Alexander 1977), for example, proposes that placelessness can be avoided by applying validated patterns reviewed by multiple architects. In 1929, Clarence Arthur Perry (Perry 2003), the planner and founder of the Regional Planning Association of America, proposed the neighbourhood unit, with a similar absence of empirical evidence. The same thing could be said about C. S. Stein, who 50 years later published Towards New Towns for America (Stein and Mumford 1966), or the contemporary Urban Village Movement in the UK (Aldous et al. 1992) (Huxford 1998). The slow cities movement (Knox 2005) (Pink 2007) continues this trend of proposing solutions without providing objective evidence to support the conclusion that their solutions will inherently produce the outcomes they propound.

The subject of place in architecture is not a new one. Architect Norberg-Schulz (NorbergSchulz 1971) (Norberg-Schulz 1976) (Norberg-Schulz 1980a), strongly influenced by the philosophy of Heidegger, wrote about this in the 1960s to 1980s, which was very much the basis for this thesis. However, his work was not alone; a number of other architects and theorists shared his ideas, such as Charles Moore and David Leatherbarrow (Mostafavi and Leatherbarrow 1993). It is an objective of this thesis to see whether these studies of place that are strongly grounded in the work of phenomenological investigation (Seamon) can be, at least in some part, empirically tested and brought into the realm of the discursive design function. It is the contention that doing so may expose the concept of place for further critical study with the longer-term objective of creating methods and techniques that might provide an opportunity to build in a sense of place, as called for by the critics mentioned above. It is the intention of this thesis to create some kind of framework with which to help elicit some aspects of place that may be of use to architects and planners of 'place'.

The place of place

There has been substantial research on the subject of place, principally in the realm of humanistic geographers using a phenomenological approach, but also by social psychologists, planners and architects. The subject of place is, as Cresswell (Cresswell 2004) describes, quite a broad one. A country can be a place, a planet can be a place and as Tuan (Tuan 1974) points out, a favourite armchair can be a place as well. For this thesis, it is simpler to restrict the view of place to those which might affect or be affected by the built environment, such as buildings and urban environments. So what is place? As mentioned, Norberg-Schulz was strongly influenced by Heidegger's views on being, i.e., the practice of existing in one place. For Norberg-Schulz, it is this process of inhabitation that strongly defines place (Norberg-Schulz 1976).

The modern foundation of the research on place itself lies with the work of two geographers, Edward Relph and Yi-Fu Tuan. For Relph (Relph 1976b) a trivial reduction of place might be to consider a house as a building but a home as a 'place'. Memorably, the computer scientists Harrison and Dourish (Harrison and Dourish 1996) introduced place by saying that 'space is the opportunity but place is the reality'. This separation between space and place reaches as far back as the ancient Greeks, such as Aristotle and Plato (Jowett 1872), who differentiated between place (Topos) and space/location (Chora). '(Chora) never alters its characteristics. For it continues to receive all things, and never itself takes a permanent impress from any of the things which enter it, making it appear different at different times', while a place (Topos) 'is understood with our senses'.

The humanistic geographer Yi-Fu Tuan (Tuan 1974) (Tuan 2001) introduced the concept of 'Topophilia', the love of place. This is a concept that feels very self-evident; for example, a home is a place of very strong emotions, yet for strangers it is just a building. We might feel strongly attached to the building and strongly resist changing the location of our home. For others, such as Relph, having a strong negative response to a location also implies the presence of place; for example, a student's association with a hated school implies the presence of place, or as Relph (Relph 1976b, 141) says, 'Places are fusions of human and natural order and are the significant centres of our immediate experiences of the world. They are defined less by unique locations, landscape and communities than by the focusing of experiences and intentions onto particular settings.' From this we might begin to think of place as that which makes a location meaningful.

Is place then just a set of arbitrary associations attached to a location or area? For an individual, this might be true; we might have a special place, a place which is important to just ourselves. Does this imply that any random location is capable of being a place, provided some meaning is applied to the location? Relph (Relph 1976b) introduced the idea of placelessness, which is almost the reverse of place. If place is something that has what Norberg-Schulz (Norberg-Schulz 1980b) calls genius loci, the spirit of a place or the character of a place (to slightly anthropomorphise place), then placelessness is the response to the lack of genius loci, the absence of individual character or identity, a place that is ubiquitous. This was

Relph's intellectual response to the growth of roadside strip shopping malls and fast food chains, but also to places like Disneyland or even historic sites that have been overly commodified as tourist locations. Thus, it seems that not any place will do. Yet, the idea that construction practices can contribute negatively to place seems to suggest that they can also contribute positively to it.

For Tuan (Tuan), place comes into existence signalled by being given a name when its character is strong enough for it to differentiate itself from its surroundings. It is then said to have a strong "sense of place". This place is a phenomenon, which in many settings can be said to exist independently of an individual but is rooted in their experience of a place. Thus, when Norberg-Schulz discusses the genius loci of a place, this is not a folk, Romantic, Neoromantic, tribal, spiritual, or religious use of the term, but is an expression of the more philosophical and architectural response to the phenomenon of place.

If we are to build places rather than buildings and urban agglomerations for the millions of people we expect to house in the coming years, how can designers avoid duplicating the kinds of placeless locations they have been criticised for building over the last fifty years across America and around the world? Indeed, can intentionality in design bring about place in the same way it has accidentally excluded place, making the placeless? This would require that place be associated in some causative way with some design choices. Finally, given the global design challenges to reduce energy consumption, can we design place without reproducing historic models of well-known places? This would require a deeper understanding of place unfettered by purely historic reproduction.

To approach this, we need to begin at the lowest level with Relph's place and Tuan's space differentiation between space and place (indeed Tuan's book is entitled Space and Place).

Space and location

It should be pointed out at this stage that it is more common for geographers to use the concept of space rather than location when differentiating between the social concept of place and the external reality that has been referred to as location. This was done deliberately to try to deconstruct the conflict involved in the use of the term space. Given the possible readership, it is important to emphasise that there is a difference between the geographical use of the term space and the architectural interpretation of the term. Geographer Helen Couclelis gives an excellent introduction to the use of space in geography, stating that there are five uses of the term (Couclelis 1999). The first is space in the mathematical sense of the term. Up until the 20th century, it was likely that the mathematical usage of the term space and the physical term were in accord. This is the concept of absolute space, the sense of Newtonian mechanics: as Couclelis states 'space is a neutral background against which the positions of objects can be pinpointed and their motions described.' Modern mathematics sees this as one kind of space and regards it more as a 'mathematical concept generally regarded as a set of points having some specified structure' (New Oxford American Dictionary) (McKean 2005). As Couclelis states,

> *'new types of space are being introduced into geography such as the gridded lattice of cellular*

automata and the geographical fractal space suggested by Batty' (Couclelis 1999) (Batty and Longley 1994).

The second type of space is that of physical space. This is the space unsullied by non-Euclidean geometries or relativistic space. This is the space of traditional geometry and trigonometry. This is very much the kind of usage for space that I have adopted by the use of the term location in the text of this chapter so far.

The third type is described by Couclelis as socioeconomic space. This is an idealised geographic space, a landscape (a fragment of the planet earth) that contains, for example, a location, but rarely elevation or topographic space. When building a socioeconomic model, it might be germane to consider the effects of distance upon the model but not to consider the absolute location. This is the kind of space used in the location theory originally developed by Von Thüne (1826). Thus in this model, 'space is uniform and neutral in character'. Socioeconomic space is still an ideal, and could be seen as an extension of the first and second types of space.

The fourth type is labelled behavioural space. Behavioural space appears to be an extension of the objective spaces described so far. Given the ground truth given by physical and socioeconomic space, we can begin to see how people's perception of space is an 'inferior distortion' of 'real space'. For example,

> *'People may patronize a neighborhood store for years in the mistaken belief that it is closer to home than some other… the space people experience and in which they make daily decisions differs from the objectively definable, theoretical space that falls under the rubrics of mathematical, physical and socioeconomic space' (Couclelis 1999, 255).*

Behavioural space is then a more subjective space; it tends to be the space of the individual. One common example of behavioural space is that of the cognitive map. Cognitive maps were originally developed by Lynch (Lynch 1960), but were expanded to be a statement of the spatial structure of an individual's environment by Downs and Stea (Downs and Stea 1973) (Downs and Stea 1977) and Gould and White (Gould and White 1992). The world of the cognitive or behavioural map is still apparently viewed as a distortion of the 'real' map, rather than as a basis for a new type of egocentric mapping.

Finally, the fifth type is experiential space. 'This is the kind of space human beings actually experience before it is passed through the filters of scientific analysis' (Couclelis 1999, 229). This is partly the space of the body, sensorimotor space, the ability to catch a ball or pick up a kitchen knife without hurting oneself, or indeed stand and walk over an uneven surface on two feet (a process that is still difficult for a robot to achieve). This is the space of practical skills over the analytic space described so far. This is also the space of meaning, the space of genius loci, the space of the gods on Mt. Olympus, the space of the homeland and the sacred. This is very much the space augmented by human experience and meaning, the kind that humanist geographers refer to as place. As Couclelis says 'For many cognitive scientists and linguists these days, experiential space is considered fundamental enough to underlie all human thinking and language (Lakoff 1987)'.

Yet one is left puzzling over these categories. What is interesting is that for Couclelis, there is no place for topological space, although it might be argued that this might not be thought of as space at all. A graph or network has no strict spatial layout – or rather each graph has an infinite number of possible 2-dimensional layouts, each one with no direct effect on the properties of the graph. Worse still is the concept of the weighted graph where the network and some real number value between segments are maintained as weights, but the distance is not.

Architectural Space

What makes all of these alternative conceptualisations of geographic space interesting is that they have little apparent relation to the architectural concept of space. According to architectural historian Forty (Forty 2000), the concept of space was not in the architectural vocabulary until the 1890s. He suggests that earlier terms were 'volumes' and 'voids', with space used as a synonym or in the context of 'void spaces'. This leads us to an entirely different usage of the term space from that which we have experienced so far in the geographical setting. According to Forty, the term space in architecture evolved from German writers who used the term Rasum. 'Rasum at once signifies both a material enclosure, a "room" and a philosophical concept' (Forty page 256). Forty said that 'Much of the ambiguity of the term 'space' in modern architectural use comes from a willingness to confuse it with a general philosophical category of 'space"'. For example, an American architect, professor and author Neil Denari, is quoted as stating, 'What I am really interested in is designing architectural space' (Denari 1993). Frank Lloyd Wright is quoted as saying, "Space is the breath of art" or "the space within becomes the reality of the building"; or Philip Johnson, "All architecture is shelter, all great architecture is the design of space that contains, cuddles, exalts, or stimulates the persons in that space"; or Le Corbusier said that "Architecture is the learned game, correct and magnificent, construction of space assembled in the light". These quotes appear to be based on the belief that architects make space.

Henri Lefebvre's book 'The Production of Space' (Lefebvre 1991) identifies the problem and tries to differentiate between what he terms 'lived' space and the space conceived by the mind. The state space as conceived of by the mind is introduced by Kant in 'The Critique of Pure Reason' (1791). 'Space,' he writes 'is not an empirical concept which has been derived from outer experiences. Space exists in the mind *a priori* as a pure intuition, in which all objects must be determined' (68) and contains 'prior to all experiences, principles which determine the relations of these objects. Therefore, solely from the human standpoint we can speak of space, of extended things. (71)' Forty quoted Kant (Kant 1933).

Therefore, we have a philosophical concept of space as 'part of the apparatus through which we perceive the world' (Forty). This could be interpreted as a philosophical translation of the experiential space, the fifth type of geographical space. This concept of space as being an inherent mental concept necessary to understand the world fits nicely with the concept of space as a conceptual realm or space as the city in the mind, as used by Hillier (B. Hillier and J. Hanson 1984).

The second type of space is the void between spaces, the 'lived space' to use Lefevre's term.

This is the space of Adolf Loos Raumplan from the traditions established by Semper; here space is 'defined'. The architectural space, unlike geometric space, is artifice, the product of construction rather than an infinite resource upon which place is located. Architectural space is bounded, and it is the act of bounding that in many ways defines architecture as an endeavour. As such, the elevation of place above space appears to be counterintuitive to the architect reader. This kind of space is closer in many respects to a naked 'place'. Looking at the usage of the term and the poetics of architectural space, it is tempting to more closely identify the architectural term 'space' with the geographical term 'place', but this would denigrate both definitions. For example, there is the question of the neutrality of space. Hillier, for example, asserts, 'Space is more than a neutral framework for social and cultural forms', but then goes on to say, 'configuration exists when relations between two spaces are changed according to how we relate one or the other, or both, to at least one other space (B. Hillier 1996a)', clearly implying that a building can be divided into spaces. At the core, what appears to make architectural space different from place is that space can be constructed and could be left unoccupied and remain a space, whereas place might be thought of as occupied space but one in which some kind of emotional attachment evolves. Yet places like airports for Relph are 'place-less' but yet hold emotional attachments (fear, dread, anticipation, excitement of a holiday or the regret of a trip ruined, the joy of reunion) but this would detract from the core of Relph's message that place-less locations are just the products of ubiquity having no relationship to the wider location. From Tuan's and Agnes' perspective we might conclude that a place is location with meaning, but this would bring into question the inherent property of meaning any architect might give to a space.

By creating the field of space syntax, Hillier shifts the conceptualisation of space closer to the conception of place. For Hillier and others in the field, space is the fundamental object of study but is not a discipline in its own right (as building morphology might be). Rather, it is studied in relation to how the object of occupation (the building, urban environment, etc.) functions with its occupants or inhabitants. Space syntax could be defined as the interaction between spatial configuration and social phenomena, aesthetic or cultural. One of the clearest demonstrations of the confusion between Space (a singular geographic space) and space (an example of the plural, a space as one of many in a system) is the use of the term spatial analysis. For the geographer, spatial analysis is the use of metric space to numerically model geographically based problems. Therefore, the term 'geostatistics' could be substituted for spatial analysis. For the architectural researcher, space (or rather spaces) can be the object (rather than the domain) of an analysis, leading to spatial analysis being the study of space(s). Given that a space syntax analysis is topological or angular, the lack of explicit metricity (type two space in geography) appears to render a term like syntactical spatial analysis as dysfunctional or even paradoxical.

Space in the architectural sense has a number of detractors, as Hillier says:

> *'space seems to be the emptiness surrounding things rather than a thing in itself, and so does not participate easily in the processes by which entities*

> *are identified and named by human minds. If we try to say that 'space' is a universal term for the many individual spaces which we experience, in the same sense that 'bird' is a universal term for an unimaginable number of individual birds, we find that the individual 'spaces' referred to seem not to be well-defined entities with recognisable shapes, but emptinesses with arbitrarily many shapes and sizes, sometimes (as in the urban case) continuous rather than discrete, and often lacking any property in common .' (B. Hillier 1996b)*

Scruton (Scruton 1977) argued that the architectural notion of space is a delusion. For him a space of the building site is the same as the space of the cathedral built on top of it. Given that all has changed is the physical form he concluded there is no 'space in its self'. Tschumi (Tschumi 1996) said that space is 'some process or agency' that is treated by subjects as an intermediary to get something else done rather than as an object in and of itself that is there is not space with out event.

> *'The effect of this preference for spatiality over space in the social sciences has meant that the social sciences simply do not address space in its primary experiential form as the real patterns of space which confront us in the real world of everyday life.'*

Hillier goes on to support the notion that space is a 'thing' rather than an abstraction, asserting that space is a phenomenon that we directly observe in everyday life, 'the real cultural manifestation of space as complex patterns 'out there' embodying social ideas, in favour of a view of space as the spatiality of a biological or cultural process'. This view of space rather than location has the same kinds of questions asked of it as location does in humanistic geography. Does space interact with the social notion of place? Hillier continues:

> *'The first is that we have to learn to think of space not as the background to human activity, as we think of it as the background to objects, but as an intrinsic aspect of everything human beings do in the sense that moving through space, interacting with other people in space, or even just seeing ambient space from a point in it have a natural and necessary spatial geometry: movement is essentially a linear activity, interaction requires a convex space in which all points can see all others, from any point in space we see a variably shaped visual field we call an isovist, and it is by accumulating these as we move through the complex patterns of space we find in buildings and cities that we somehow build an enduring picture of the pattern of space as a whole.' (B. Hillier 2005)*

So, space for Hillier is an active participant in the city and society. Perhaps we can think of it being equated with place. Ultimately for Hillier, space exists due to its relatedness (the network spaces form), which is distinct from the spatial field we can understand from geographic and mathematical space.

To help to clarify the thesis it is important to define terms specifically (see table 1). For the purposes of this thesis:

I will use the term place to refer to the place common to human geography, but will not address the full range of place common to human geography. Instead, place will be generally limited to buildings and urban neighbourhoods.

	Architecture	Geography	Lefebvre	Plato	Thesis
Cognitive	Location	Space	Absolute space	Chora	Location
Behaviour or conation	Space			Chora	Space
Affective	Place	Place	Social space	Topos	Place

Table 2:1 Comparison of meanings of space, place in differing literature.

I might call this neighbourhood-place. This notion of place is the one closest to the one Lefebvre calls socially produced space or social space, the one that Plato calls Topos.

In opposition to the geographic use, the term space will be used in the architectural sense described above.

Finally, I will use the term location or geometric space to refer to the geographic concept that generally uses the term space. This is what Plato calls Chora and Lefebvre (Lefebvre 1991) refers to as 'absolute space'. This is the notion of location in the highly Cartesian sense; a point has a location in space, for example, a longitude, latitude and elevation. It has connotations of the most rational and objective view of location-space. I will tend to use in accord with the second definition for space in the Couclelis taxonomy of space.

The relation between place and location

Having settled on definitions for the terms, we must return to the core investigation of place. Most parties agree on the separation between location and place, but a question arises about the degree to which place depends or is related to location. At this point there appears to be no consensus. For example, Canadian geographer Edward Relph certainly believes that place is independent of location. Relph quotes Susanne Langer when she states that place in one significant social sense does not need a fixed location at all.

> *'A ship constantly changing its location is nonetheless a self-contained place, and so is a gypsy camp, an Indian camp or a circus camp, however often it shifts its geodetic bearing. Literally we say that the camp is in a place but culturally it is a place. A gypsy camp is a different place from an Indian camp though it may be geographically where the Indian camp used to be' Susanne Langer 1953, quoted in (Relph 1976b, 29) (Langer 1953).*

Clearly we can extend the ship analogy, we know that the world is turning in outer space (space in the astronomical sense) relative to the sun. Thus, any city is moving through outer-space relative to the Sun at a high velocity, so any city in the world is also moving in a manner similar to the ship through location-space. It seems safe to assume that the location Langer refer to is geographic location. Yet, we know that the continents are moving slowly; so each city is moving very, very slowly relative to the geographic norms. Thus, since we cannot say that any location is truly fixed, either interpretation appears to confirm Langer's point.

This idea of complete separation, or rather independence, is not held by all. The political geographer Agnew (1987), as quoted by Cresswell (Cresswell 2004), identifies location as a fundamental aspect of place, calling it a 'meaningful location'. Agnew is not alone; many would agree that place is a separate entity from location, or rather that location forms the basis for a place; (Tuan) (Buttimer and Seamon 1980) (Malpas 1999) (Tuan 1977) all appear to follow this view.

The computer scientists Harrison & Dourish use the following example:

> *'The same location—with no changes in its spatial organisation or layout—may function as different places at different times. An office might act, at different times, as a place for contemplation, meetings, intimate conversation and sleep. So a place may be more specific than a space. A space [location] is always what it is, but a place is how it's used.' (Harrison and Dourish 1996)*

This gives rise to the question of whether location is neutral and space a passive neutral component in place, as Harrison and Dourish contend.

Yet, in some respects Relph appears to contradict this view. A second term that he introduces involves a lack of authenticity. Locations are placeless because they are inauthentic. One example Relph uses is that of a museum constructed of several vernacular historic buildings that have been moved to the museum site. In their original locations, these buildings might not have been placeless, but once moved they lack authenticity due to their lack of a relationship with their surroundings. This suggests that a relationship with the surroundings is important, and the loss of authenticity that occurs when moving an object would imply that relationship is partially related to place and location.

Perhaps it might be argued that the relationship between place and location is rather overly broad and, in the context of this thesis, overly general; a glade or an armchair can be a place, as can an entire continent. Thus, as mentioned, it makes sense from the perspective of this thesis to limit place to a more specific view of the neighbourhood place. This goes against the more open and encompassing view of place that phenomenologically based geographers would use, but fits well with the empirical basis of this thesis. In this sense, neighbourhood-place is a geographically bound community. A community is a purely social object and can exist across space for any community of interest – Star Wars fans, for example, can and do exist without geographical limits (a term we will see later Hillier calls trans-spatial). On the other hand, this lack of the geographical bounds for a community is one of the aspects of neighbourhood that have caused the criticism of being placeless. What makes neighbourhood useful from this context is that it exists semi-independently of the individual. We might have a favourite place as an individual but a neighbourhood is shared between people and, as Taylor (Taylor 1981) points out, has significance in the use of a mutual sign for its existence. Thus we can be sure that Camden Market as a place exists because the entities involved in it overlap. If Camden Market was a teapot to one person and an umbrella stand in California to another then it might be doubted we are talking about the same thing. The spatial colocation of references asserts the identity of Camden as a thing. It is a collective notion that is useful in that it is shared between a number of individuals, and as such it is more open to empirical study as a phenomenon.

The economist and planner Webster (Webster 2003) observed in one study that neighbourhood is a strong factor when choosing a new house. This suggested that neighbourhoods must exist, since they are a strong factor in house buying decisions. We can be fairly certain then that neighbourhoods exist, even if only from an economic point of view. Yet, if places are purely restricted to singular subjective associations made by individuals, why would such places have common names (Taylor, Gottfredson, and Brower 1984)? As Taylor (Taylor, Gottfredson, and Brower 1981) suggests, we use names to locate things and refer to them in language, suggesting that a neighbourhood place is a thing.

One of the aspects that makes a neighbourhood place different from all of the other types of places is that it is shared by a number of people. A common emotional attachment can exist to a wider area, including some portions of the area that have not been visited (someone might say they love New York or are a New Yorker, while they are unlikely to have ever visited every location in New York).

Place attachment

Sociologists and some geographers refer to this as 'place attachment' (Willmott and Thomas 1984) (Low and Altman 1992) (Giuliani and Feldman 1993) (Manzo and Perkins 2006). This concept of place attachment implies that a group of people share some common emotional attachment to a specific set of locations.

So, what is it about a neighbourhood that makes it a neighbourhood? From the work of Relph and Tuan, it is clear that we have an intuitive understanding and appreciation for the concept of neighbourhood.

> *'The relationship between community and place is indeed a very powerful one in which each reinforces the identity of the other, and in which the landscape is very much an expression of communally held beliefs and values and of interpersonal involvements.' (Relph 1976b, 33)*

Unfortunately, aspects of this appreciation are hard, if not impossible, to appraise. This could be seen as another case of Hillier's language analogy (Hillier and Hanson 1981); we speak to each other in a nearly grammatical way, yet we have no direct access to what it is about our sentence construction that makes one sentence grammatically correct and understandable and another not. From this point of view, we experience language but are not conscious of it. It is possible to see our understanding of space, and in this context place and neighbourhood, as more concepts which we intuitively know but cannot bring into the discursive realm. We live in our use of space, a concept that Relph (Relph 1976b) referred to as existential insideness and Seamon (Seamon) referred to as the 'life-world', the world we live in over the world we can describe, analyse and reflect upon. The concepts of place and neighbourhood then could be both present and real but inaccessible.

While we can agree that a number of people might be attached to a location or place, we have not said how they identify the location or neighbourhood as that place. We have mentioned that it is likely to be through a process to which we have no direct access. We can, however, begin with a number of conditions that might make the process of identifying a potential hypothesis for place possible. First, we can agree that we can experience a neighbourhood (Webster 2003), that is, we might live in a neighbourhood and be aware when we have left it, and so the neighbourhood must be signalling its presence and absence. Yet, how is it doing this? Are the clues for our awareness purely visual? Montello, for example, criticises space syntax for ignoring surface elements:

> *'the superficial appearance of the environment is nearly completely ignored by space syntax, including surface colours, textures, and patterns. Yet, environmental differentiation is an important predictor of how people mentally organise the environment and maintain orientation' (Montello 2007).*

If these factors are crucial then, for example, might a blind or deaf person have a real direct concept of place? Common sense suggests that blind people can have a sense of neighbourhood and, as such, an awareness of neighbourhood must indicate its presence to us on a multi-sensory level (or we might have to take the alternative stance that the visually disabled are only capable of what Peet (Peet 1998) would call 'vicarious insiderness' in relation to neighbourhood, a concept which does not feel viable).

Norberg-Schulz (Norberg-Schulz 1976) introduces the use of the human analogy. This is place as a person, a concept born out by the term genius loci, the spirit (divine incorporeal person) of a place. This concept goes back to the Romans, but has emerged in many primitive and not-so-primitive cultures, such as the Arthurian legend of the Lady of the Lake. Clearly, we can be attached to place in a way analogous to being attached to a person. We can take this further by asserting that a place has character, that is, it has some distinctive and individual qualities. As Norberg-Schulz says, 'A place which according to local circumstances has a particular identity. This identity or 'spirit' may be described by means of the kinds of concrete qualitative terms Heidegger uses' (Norberg-Schulz 1976). This suggests that if it is the qualities of a space that reflect the genius loci of a place, then the roots for place attachment must be in the physical world. It might be argued that, as an architect, Norberg-Schulz would believe that place is attached to the characteristics of a location and that as such the process of architectural design can either hinder or afford the possibility for others to attach to place.

Sensing place

The American urban planner Kevin Lynch certainly considered that while place was in the mind it was also attached to aspects of urban design. If place is not associated with some kind of external identity, then it appears difficult to associate any character, and so identity, to a location, and hence form a general neighbourhood place. Lynch introduced the term "sense of place" (Lynch 1981, 131). For Lynch, this sense of place is the ease with which Lynch's five elements (paths, edges, districts, nodes and landmarks) can be linked to events, experiences and mental representations, thus forming "place identity".

One possible solution to this is to view place as in the mind, and assume that some invisible aspect of a space is responsible for the shared response, leading to the shared notion of place. Kevin Lynch (Lynch 1960) (Lynch 1965) supported this by performing sketch mapping tests on inhabitants. From this he developed five elements that he claimed were necessary for the proper construction of mental images. An area with a strong mental image he termed a 'legible' image. Lynch's five elements (path, node, districts, edges and landmarks) are interesting in that they are primarily spatial markers rather than visual ones. It should be observed that the concept of spatial continuity does appear to solve the first problem of place as a continuity of identity. For example, while the buildings in the city of London do appear to change over history, the street system is relatively constant. It is similar with Soho in New York, the street pattern is broadly that of the original 18th century pattern; this continuity of space would sit naturally with the continuity of the Soho 'neighbourhood-place'.

Lynch's work with his five elements of legibility does introduce a number of problems. First, his empirical measures of space are entirely dependent on inhabitants drawing mental maps. As a constructive procedure or a method for designers to use, this is problematic. Does Lynch expect that all paths, nodes, districts, edges and landmarks are equivalent and just encouraging the designer to use them would create legible environments and so lead to places? What if the designer might construct something as a landmark or an edge that the general population would not consider as such? The inability to get potential participants to live in as yet unrealised neighbourhood then to get them to build their mental maps which his cognitive mapping technique would record and present for analysis. Lynch's method could be embodied in a prescriptive template in the style of Alexander (Alexander 1977) but this could be criticised as restricting the designer to reproduce old styles of urban design and so fail to be both flexible and responsive to modern demands (for example the solar orientation constraints of green design). While Lynch's work does suggest a possible role for space as the substance of (or medium of transmission for) the character of place, his work specifically appears not to lead to a successful flexible design strategy.

In both *The Social Logic of Space* (B. Hillier and J. Hanson 1984) and *Space is the Machine* (B. Hillier 1996b), Hanson and Hillier create a new and possibly more functional mode of enquiry. First, they posit a purely spatial hypothesis. Second, the view they create is largely an objective one; an axial map or convex map is extractable from the spatial configuration. This creates a very design-friendly process. Third, the representations separate the subjective (people's response to space) and objective (the spatial map) elements. For example, the syntactical model, as it might be called, ends up independently testing the configurational properties of space against objective and empirically observed behaviours. For example, if a person believes that community requires interaction, they can use the density of pedestrian movement as an intermediate variable when considering the impact of a spatial design on interaction. This separation of observation and the test variables needed for statistical comparison is also quite useful and has led to a number of tests of the method in the real world. It should be observed that Hillier & Hanson (B. Hillier and J. Hanson 1984) noted that pedestrian movement appears to be accounted for by configurational measures dependant on structures created by the intersection the axial line and convex space. This appears to echo Tuan's (Tuan 1974) concept of space being about movement through it. Tuan goes on to suggest place being about something stationary (dwelling), an idea which is taken up by Seamon, as will be covered later.

Intelligibility

In *Space is the Machine* (B. Hillier 1996b), Hillier also introduced a concept called intelligibility, which invites comparison to Lynch's concept of legibility or imagability (see R. C. Dalton and Bafna, 2003 for further comparison).

> *'The property of 'intelligibility' in a deformed grid means the degree to which what we can see from the spaces that make up the system - that is, how many other spaces they are connected to - is a good guide to what we cannot see, that is, the integration of each space into the system as a whole. An intelligible system is one in which well-connected spaces also tend to be well-integrated spaces. An unintelligible system is one where well-connected spaces are not well integrated, so that what we can see of their connections misleads us about the status of that space in the system as a whole. We can read the degree of intelligibility by looking at the shape of the scatter. If the points (representing the spaces) form a straight line rising at 45 percent from bottom left to top right, then it would mean that every time a space was a little more connected, then it would also become a little more integrated - that is to say, there would be a perfect 'correlation' between what you can see and what you can't see.*

> *The system would then be perfectly intelligible. In figure 3.14e, the points do not form a perfect line, but they do form a tight scatter around the 'regression line,' which is evidence of a strong degree of correlation, and therefore good intelligibility. In figure 3.14f we find that the points have become diffused well away from any line, and no longer form a tight fit about the 'regression line.' This means that connectivity is no longer a good guide to integration and therefore as we move around the system we will get very poor information about the layout as a whole from what we see locally. This agrees remarkably well with our intuition of what it would be like to move around this 'labyrinthian' layout.' (B. Hillier 1996b, 107)*

Hillier observes that for well-formed areas there is a strong correlation between connectivity and the global integration measure. From an experiential point of view, this is a measure that compares how many alternative routes one can see with how central that route is within the global system. This is effectively a measure of how much the local observable visual vista can be used as a guide to the wider urban landscape.

Synergy

A second measure introduced by Hillier, called 'synergy', is similar to intelligibility. It is the measure for an area, of the correlation between global Integration and location Integration (a more detailed introduction to synergy can be found in chapter 4). Hillier suggests that this is a measure of how much the local street system is a reliable predictor of the global configuration. Synergy appears to be strong in named neighbourhoods and weak over random areas of London. This notion of looking at the integration values for a group of spaces was also used by Read (Read 1999) who looked at neighbourhoods in a Dutch city using maps of the average integration (for a space the average integration is given by the average of all the integration values of its connected neighbour spaces) and suggested that for Dutch settlements the maps appeared to be related to neighbourhood.

It seems natural that both the Read average integration measure and the Hillier concepts of intelligibility and synergy appear to be prototypes for a purely spatial measure of neighbourhoods and so possibly linked with character or identity. As mentioned previously, it is rare for there to be large-scale interventions into an urban street pattern that permanently block roads. Therefore, if a pure spatial continuity was somehow relating the character or 'identity' of a neighbourhood, it may survive longer than the buildings.

Character in neighbourhoods

The Hillier concept of intelligibility and synergy does fail as a proxy for place in a number of points. For example, if we think an intelligible or easy to navigate location is a good neighbourhood, then as shown in chapter 4 a pure axial grid is highly mathematically intelligible (the highest value of 1.0). By building a number of non-intersecting grids it would be possible to create an area of continuous intelligibility that would contain a zone of constant intelligibility, synergy or average integration. Thus, if place is simply the continuity of character or identity, against that of surrounding areas, we would expect it to be simple to create a neighbourhood. Equally, by segregating an area from the surrounding area by creating a gated zone (or gated community), then it would be trivial to create the right conditions for a neighbourhood. This 'strong boundary' approach is indicative of the work of some researchers, such as Alexander (Alexander 1977), Salingaros (Salingaros 2000) and Newman's concept of defensible space (Newman 1997). Yet, as many such as Jane Jacobs (Jacobs 1961) would attest, this appears to be a recipe for creating large areas of dull, uninteresting housing, with little inclination toward the formation of a community. This appears to be against Hillier's own notion of neighbourhood formation (B. Hillier 1988) and fails to be enough to be a comprehensive formulation for neighbourhood-place.

The 'gestalt' of space and perceptual and emotional responses

In a critique of space syntax, Montello asserts:

> *'Above, we discussed the property of the overall shape or 'gestalt' of a path layout, as a component of layout complexity. Rooms, plazas, and convex subspaces have shape and this shape influences a variety of perceptual and emotional responses: the shape of the surrounding visible space apparently plays a key role in orientation and spatial learning as well (Hermer and Spelke 1996). The shape or pattern of path layouts is also important. As reviewed above, the angular size of turns influences orientation and disorientation. When overall path layouts have a 'good' form, they can be easier for people to comprehend. And when they have a poor form, they can be very hard to comprehend. As a case in point, unicursal mazes have path segments that twist and turn in space but do not branch. Thus we actually have no choice points that require a person to pick which way to go at the risk of getting lost. That is, they should not be psychologically challenging or stimulating. Nonetheless, they are quite disorienting, they promote mental states that seem 'altered' from our normal waking mental state. Anyone can experience this when walking along one of these mazes or labyrinths, which is verified by their widespread use over the ages in religious and spiritual mazes.' (Montello 2007)*

Montello's criticism that the angular size of turns influences orientation and disorientation which is not represented by and is not is not entirely accurate. Dalton (N Dalton 2001) introduced the concept of 'fractional integration' applied to an axial line which takes into consideration angle of turn and when applied to convex space overlap in an attempt to merge relative metric spatial properties into the overarching methodology of space syntax. Turner's work (Turner and A. Penn 1999) on Isovist integration where angular turn is taken into consideration, or Peponis et al (Peponis 2003) and Hillier and Iida's (Hillier and Iida 2005) work on segmental based angular integration also appears to contradict this part of Montello's critique.

Yet Montello's observations about the relation between a continuous path and discontinuity in orientation are real and telling. Perhaps to recognise where we are, and to do so immediately, we might need to have a number of parallel levels of consideration. We have already seen from the works of both Lynch and Hillier that we have local visible cues to the local environment, (the landmark for Lynch, Hillier's axial line) and the global environment (Lynch's district, Hillier's configuration network). As Montello suggests, there is the local response to the immediate space around us, and the global world beyond which lies partly in our minds. This world that is known but cannot be seen is what appears to be at the heart of legibility, intelligibility and synergy. Read, the creator of the average integration measure, talks about local and super grids. At the visual level, when considering what Montello terms the 'gestalt' of layout, we have the concept of the isovist, the visual field around us. The concept of the isovist was introduced by the architectural theorist Benedikt (Benedikt 1979) as a horizontal two-dimensional slice through space, typically taken from eye height, of the three dimensional view seen by Hardy (Hardy 1967) and discussed by Tandy (Tandy 1967), as a method by which to measure the visual spatial properties of an architectural environment from one point. This may have been seen as a simplification of the geographical, archaeological and military concept of the viewshed, or area where all of the surfaces are visible from a single point. It is the attempt to give the location of the centre of the isovist properties derived from the morphology of, generally, the two dimensional polygon of the isovist, which distinguishes the use of the isovist from the viewshed. These properties include the area, perimeter, second moment (variance) of the isovist boundary and third moment (skewness) of the isovist boundary. Benedikt differentiates between rays from the viewpoint that intersect some occluding surface and those that are tangential to edges in a room. Benedikt sought objective methods to combine experience and the morphology of a room into an analysis.

The work on isovists has been continued by Turner (Turner et al. 2001), who introduced the concept of a visibility graph for an isovist field or a lattice of isovist points. With this, he also introduced the concept of forming a graph by examining the intersection of isovist points and then using them in a syntactic analysis of the resulting graph. Turner's work showed a high correlation between the movements of visitors to the Tate gallery and the measurements of isovist integration. With this work he effectively merged the local scale (the scale of the body and the view from the body, along with a survey taken by the eye) with the global (the world beyond the immediately visible, the gallery in the mind). Conroy (Conroy 2001) introduced the concept of the partial isovist (what Montello called the vista), as an isovist limited by the field of view from one point. Here we see the accidental flow between the pure spatial measure of a building and the more specific model of an inhabitant. The pure isovist is a measure of a building's space from a point. The partial isovist or vista is dependant upon knowing the direction and field of view of the individual (real or presumed). Further work by Dalton and Dalton (Conroy Dalton and N. Dalton 2001) introduced new concepts, such as drift (the vector difference between the centre of the generated isovist and the centre of gravity of the resulting polygon). Further work by Franz and Wiener (Franz and Wiener 2005) introduced the concept of revelation, the sum of all the possible changes in an isovist area as one moves from one point to all of the other surrounding points in a regular lattice of isovists from the starting point. Their work suggests that our appreciation of the world is a response to isovist properties. For example, in their tests, participants that were asked to find the best place to hide tended to find the point in space with the smallest isovist.

To clarify the argument, while humanistic geographers have had concern about separating 'location' from place, we have seen that there is no similar strong distinction between a network of spaces and place. There has been considerable research that appears to back up the claim that space (in the architectural sense) does appear to influence our movement, and hence, for example, our propensity for interaction. Further work such as Franz and Wiener (Franz and Wiener 2005) or the Environmental Psychology of Kaplan & Kaplan (Kaplan and

Kaplan 1982) in turn supports the notion that we are spatially sensitive and that there are emotional responses to space that might form a component of place.

Previous and contemporary work on place in space syntax

This thesis is not the first time parallels between space syntax and notions of place, and particularly neighbourhood place, have been explored. Much of the previous work has looked not at the humanistic geography such as Relph but a more core phenomenological approach. Phenomenology broadly in this context focuses on the investigation of consciousness and the objects (the phenomena) of direct experience.

Perdikogianni (Perdikogianni) identifies the similarities between place and 'configured space'. She also identified space syntax as a link between the phenomenological view of place and cognitive psychology, citing the notion that space syntactical representations are highly embodied in our experience of place, as are those of phenomenology and cognitive psychology. In addition, she situates space syntax away from the direct correspondence model between space and neighbourhood, while leaving open a more complex relationship (Julienne Hanson and Bill. Hillier 1987), to distinguish between approaches that theorise that the relationship between space and society is expressed as a correspondence model (Alexander 1977) (Lynch 1981) (Newman 1996) and those that suppose that an urban environment is heterogeneous and that space simply plays a positive role in controlling and generating this heterogeneity (Jacobs 1961) (Appleyard 1981). Finally, Perdikogianni also created a link between the physical environment and the possibility of the phenomenological experience of place. 'However, within the notion of "place" the experience of this physical environment is its intrinsic characteristic, at least in its phenomenological definition, considering a city's major actor, the individual.' (Perdikogianni). This is an excellent introduction to the relationship between place and space syntax and is certainly a call to bring place and the experience of the city closer to empirical analysis:

> *'This currently forms the major scientific challenge: to develop methods to bring together the analysis of urban structure, design and morphology with the broadly qualitative investigation of individual and community perceptions, attitudes and aspirations'.*

However, it fails to theorise any mechanisms by which this aim may be brought about.

Sailer and Penn

After performing a combined phenomenological and syntactic analysis of a workplace, Sailer and Penn (Sailer and A. Penn) observed,

> *'A phenomenological perspective may contribute to space syntax by not only offering insights into socially meaningful topics to research, and as shown above by helping to identify the dimensions of interest, but also by suggesting ways in which to interpret the data. It adds detail, sensitivity and empathy to the purely statistical observation of phenomena. This seems to offer an example of what Michael Wheeler has described as the "Heideggerian philosophy-science nexus", in which incorrect constitutive assumptions are propelled towards better assumptions by the force of explanatory difficulties in the face of the phenomena of the world.'*

While it examined an office workplace rather than a neighbourhood place, this paper did show the positive results that can be achieved by using a combined approach. However, it did not push the field to a extended space syntax theory; rather it attempted to apply the current methods and techniques in combination. The conclusion about the Heideggerian philosophy-science nexus leads to the next paper by Hillier.

Hillier

Hillier (B. Hillier 2007) also examined the relationship between space syntax and the phenomenological views of place in the context of forming a theoretical bridge between what he terms social physics (abstract, largely mathematical models of city growth) and phenomenology. For Hillier, social physics models suffer from being poorly grounded in the observable phenomena of everyday urban experience. That is, the models are highly top down and frequently based on abstract mathematical principles rather than empirical observations of the urban environment and have specific regions of application, such as transport modelling[1]. Hillier also critiques phenomenology.

> *'The neglect of the parts by social physics is however complemented by the phenomenologists' neglect of the whole. Because phenomenologists are preoccupied with experience, they are by definition preoccupied with the parts, and seem satisfied with a picture of the physical whole as abstracted as the social physics view of the parts. This seems equally regrettable. Although we experience cities a bit at a time, our sense of the city does not reflect this fragmentation. On the contrary, our sense of a city is made up of a sense of its differentiated parts and the transitions between them. It would be too obvious an error to confine the experiential study of the city to the study of its parts. The defining dimension of our urban experience is of how the parts form some kind of complex whole. This is what we mean when we say 'Boston', or 'London' or 'Sydney'. The greatest phenomenological puzzle about the city is perhaps what we mean by these names.'*

Hillier then goes on to critique what he terms social physics' large scale theoretical models, which have interesting emergent properties (such as self-organisation) and show how the parts may relate to the whole but largely have no grounding in the human experience of the world.

> *'The fact that cities exist at one scale, but are experienced at another, helps trap us between an objectivist and rather abstracted view of the city as a whole and a subjectivist and phenomenological view of its parts. From the point of view of building a theory of the city, these two polarisations between the physical and the experiential, and between the local and global scale - seem the wrong way to go. If we think either of how the self organising city comes into being as the product of innumerable human actions guided by thought, or of how cities work as complex networks of spatial and social differentiation and dynamics, then it would seem, that we must give an account of the physical in terms of the experiential, and vice versa, and the local in terms of the global, and vice versa.'*

For Hillier, space syntax, while rooted in an empiricistic scientific approach to the understanding of urban form, is in many ways complementary to the methods of phenomenology and shows that second generation social physics models, such as Batty's (Batty and Longley 1994), are being informed by the spatial network models typified in space syntax itself. Hillier then proposes that space syntax forms a potential bridge between the local holistic view of phenomenology and the global scale social physics model of the city, but does so in an empirically testable scientific framework. While this might strongly suggest that some kind of empirically grounded theory of place might arise, it does not hypothesise a mechanism for how this might be done.

1. This might be characterised as engineering models rather than models of exploration.

David Seamon

From the phenomenological point of view, architectural and planning phenomenologist David Seamon (Seamon 2007a) appears to be equally unequivocal about what he sees as the interaction between phenomenological methods and the kinds of objective methods of space syntax. Seamon's phenomenological approach moves away from the purely intellectual basis of phenomenology's founder Edmund Husserl and sits more naturally with Martin Heidegger and Maurice Merleau-Ponty's 'reflexive understanding of everyday human life and its lived meanings' (Seamon). Seamon suggests that the objective of existential-phenomenological is 'to disclose and describe the various lived structures and dynamics of the natural attitude and the lifeworld, which always include spatial, environmental, and place dimensions.' Ultimately, the aim of existential-phenomenology is to avoid what it sees as deficiencies in the scientific method, which focuses on small specific objective elements of the world while ignoring the rich complexities of the whole. Although Seamon doesn't mention it, the contrast should be pointed out between the approaches of phenomenology and the empiricists' space syntax approach. Both believe in the primacy of data and experience but only empiricists believe in objective and reproducible phenomena and methodologies. Phenomenologists adhere to the subjective in an attempt to avoid being limited to objective phenomena. Thus, as with Sailer and Penn, we can see space syntax and phenomenology as being complementary in their approaches.

For Seamon, phenomenology is founded on the process of living in the everyday world. This is what he terms the 'lifeworld', the world in which we exist but do not pay significant regard to, since we live in it in a habitual way. Seamon explains that existential phenomenologists see our thoughts and decision making processes not as separated from the world but embedded in it, in the 'everyday way in which human beings are intimately and inescapably conjoined with the world in which they find themselves. What is analytically thought of as two—people and world—is existentially understood as one—being-in-world.'(Seamon) There is not a mind world distinction, but the mind is in the world. This idea is strongly linked to the term 'embodied cognition', which has started to emerge from physiological investigations in recent years. Thus, when we move around a familiar area, such as our house or possibly our neighbourhood, we do not plan (bring to foreground consciousness) but use what French phenomenologist Maurice MerleauPonty called "body-subject", an intelligence that is expressed through un-self-consciousness of movement or awareness. The Merleau-Ponty "body-subject" is reminiscent of the modern robotic 'subsumptive' architecture, where lower levels of intelligence are responsible for say walking, but can be subsumed by higher, more abstract levels. Thus, to walk across the room, the legs start walking while the navigational part starts to plan and will then override the legs when specific conflicts between walking and the desired direction occur. Seamon grew interested in larger scale 'body routines' or 'time-space routines', such as cooking a familiar meal or following a habitual path when going to work. Seamon observed that a number of individual 'body routines' would intermesh to form what he called a place ballet, *'a place ballet—an interaction of body and timespace routines rooted in a particular environment, which often becomes an important place of interpersonal and communal exchange, meaning, and attachment. One ingredient of a place ballet is familiarity arising from routine, since the regular actions of individuals meet together in space, which becomes a place of familiarity and perhaps attachment (Seamon and Nordin 1980)' (Seamon).*

These interactions give rise to what Relph called 'existential insideness', the place one experiences casually without forethought, juxtaposed with the ones you might be experiencing very explicitly, as when visiting a historic monument while on holiday. The term place ballet was inspired by and deliberately reflexive of Jane Jacobs' (Jacobs 1961) descriptions of the movements through well-lived streets. Place ballet is strongly based in our habitual movement through the world and, as such, Seamon suggests that,

'As both way-finding (e.g., Appleyard) and spacesyntax (e.g., (Conroy 2001), (Haq and Zimring 2003)) studies have demonstrated, there is no doubt that a mode of conscious environmental attention is important when a person is learning a new environment and literally "finding his or her way," but this situation of environmental novelty is perhaps better articulated and understood in lifeworld terms as a particular mode of place experience—what Edward Relph (Relph 1976) identifies as behavioural insideness—i.e., a situation involving a deliberate attending to place as it can be represented consciously as some set of objects, views, relationships, or activities.'

Thus, while environmental cognition may provide useful insights into aspects of pedestrian motion, it has experimental problems with habitual motion, and if, as Seamon assures us, that habitual motion is the basis for place ballet, it is debatable to what extent way finding behaviour studies will enlighten our understanding of place (although alternative

Neighboured Method	Author	Region finding	Objectively tested?	Phenomenologically grounded ?	Objective?	Comment
Average Integration	Read	Yes	No	No	Yes	Not claimed to be universal; potentially specific to Dutch cities
Strong choice lines	Peponis	Yes	No	No	Yes	Arose from the observation of Greek settlements
Segmental	Yang & Hillier	Yes	No	No	Yes	Segmental and Angular based approach but no explanation on how structure gives rise to it
Global Orientation	Raford & Hillier	Yes	No	No	Yes	By-product of work looking at regions of accuracy of integration movement prediction.

Table 2.2: Summary of previous objective neighbourhood identification methods.

methodologies might facilitate this). Or, as Seamon says, 'But very little of the time do we encounter the world through the directed attention that cognition assumes and requires, nor do we often draw on that cognition for everyday needs and situations, including environmental orientation and wayfinding.' (Seamon) For Seamon it is this place ballet that gives rise to what the humanistic geographer Yi-Fu Tuan termed 'a field of care' (Tuan 1974), the group of extended interactions between inhabitants that gives rise to neighbourhood-place. It is the role that space plays via this invisible hand guiding the spontaneous interaction of the place ballet that Seamon finds so interesting and sees as the complementary value of space syntax to phenomenology.

> *'There is normally no explicit consideration as to why experience happens as it does, whether it could happen differently, or of what larger lived structure the happening of experience might be a part. In this sense, the lifeworld is out of sight as a phenomenon, and a major aim of phenomenological investigation is to make the lifeworld, natural attitude, and the taken-for-grantedness an object of direct scholarly attention. One integral aspect of the lifeworld is place and emplacement, which have become a major research focus in environmental and architectural phenomenology (Malpas 1999) (Relph 1976b) (Casey 1993), Appleyard; (Relph 1981) (Seamon and Mugerauer 1985); (Seamon 1993) (Seamon 2007b) (Leman-Stefanovic 2000)).'*

As a researcher interested in the process of improving the experience of the world through the outcomes of architectural design, Seamon observes that space syntax has a grounding strongly based on the observation of inhabitation of real settlements (which we have seen is something that Hillier accuses many forms of social physics of ignoring as the basis for their models).

Finally, Seamon gives voice to some potential ways in which phenomenological approaches might suggest new avenues for space syntax research. 'One can imagine, for example, a phenomenologically-inspired space-syntax study of realworld neighborhoods in terms of who encounters whom in what way and how often and how these encounters contribute to participants' place attachment and to the ambience of the place.' So Seamon sees the value of empirical approaches like space syntax when they arise from phenomenologically grounded views, and calls for more work to be done on extending our understanding of place.

Previous work done on measures of neighbourhood

Space syntax has yielded research that has sought ways of identifying regions of neighbourhood (Peponis et al. 1988). (Peponis 1989) argued that axial lines of high choice (or betweenness see chapter 4) appear to be the boundaries between areas. This concept was developed by observing a number of contemporary Greek settlements. Yet, this work appears to be contradicted in a number of European cities. For example, while Oxford Street in London appears to be the border between Soho and the area to the north, many other high choice streets do not act as borders; for instance, Camden High Street in London quite happily pierces the centre of the Camden neighbourhood. The Peponis work emerged from the observations of a number of Greek settlements and has to my knowledge never been tested objectively against the inhabitants' views of neighbourhood.

Read (Read 1999) (Read 2001) (Read and Budiarto 2003) also observed that for Dutch cities, neighbourhoods appeared to be related to zones forming vertical ecologies related to gradient integration: a method whereby the value for each node is the average of the integration values for all of the connected nodes, up to three topological steps away. This method was never claimed to be universal, beyond the Dutch cities; neither was any objective testing performed to assert its validity as a method to define neighbourhood.

Yang and Hillier (Yang and B. Hillier) also introduced the concept of finding the first differential of the rate of change for the number of nodes within a bound and those above for a segmental map. They claimed that this embeddedness (EMD) identifies 'urban patchworks' (neighbourhood places in this thesis). To test the results, Yang asserts,

> *'Place names had been coined by our ancestors as descriptions of urban areas in terms of their situation, use, appearance, topography, ownership or other association, and most of them could make sense for the local residents and even tourists although their definition of an area might always be ambiguous and vary for everyone (Mills, 2001). As Central London and the Inner City of Beijing have evolved over centuries, the definition of the named areas remains more consistent across different agencies, which can be verified in the websites of Wikipedia and Wikitravel, as well as other books for tourists. The different named areas in these two cases usually reflect different urban places with specific characteristics.'*

This place name method might be capable of quickly rejecting an invalid hypothesis but, as Yang (Yang 2006) observes, the place name method can suffer from a number of potential faults, such as the intention of urban designers to generate place by giving a site a name. Hiller, Turner, Yang and Park (Hillier, A. Turner, Yang, and Park. 2007) used an extension of the Yang and Hillier (Yang, T., & Hillier, B. 2007) segmental model 9, but this time based on a metric property called metric mean distance (MMD). Their work was grounded on the observation 'that urban space is locally metric but globally topo-geometric', that is topo-geometric factors, such as topology and angle, appear to clarify large scale movement in a way that metric systems cannot. Yet Hillier has shown that grid intensification (local increases in urban street density) is vital to the structure of local retail streets. By using an angular based measure of choice (the term choice is explained in a later chapter introducing space syntax), limited by a metric radius, Hillier makes claims similar to Yang's, using detailed knowledge of the city to identify neighbourhood-like areas on a case by case basis. The results are claimed to be similar to those of Yang and Hillier's paper, with the explanation,

> *'The fact that Yang's measure of node count change of (NCr+r/2)/ (NCr-r/2) produces a very similar result to MMDr means that one measure explains the other. One interpretation of Park's Appendix to this paper would be that MMDr shows the effect of discontinuities, while node count change shows where they are.'*

In a 2004 paper, Raford and Hillier (Raford and B. Hillier 2005) introduced the concept of directional analysis, observing that regions of similar direction (global orientation) identify sub-areas that exhibit regions of correlation between integration and observed movement. While it was not claimed that these were neighbourhoods, these correlation contours did appear to be reflecting the underlying neighbourhoods and city regions in the city of Boston.

The physicist Salingaros (Salingaros 2000) (Salingaros 1998) introduced structural principles that were originally developed in biology, computer science and economics via an underlying basis in complexity theory. Echoing Hillier's intelligibility, Salingaros said that, 'A variety of elements and functions at the small scale is necessary for large-scale coherence. Dead urban and suburban regions may be resurrected in part by reconnecting their geometry.' He goes on to assert,

> *'If these suggestions are put into practice, new projects could even approach the coherence that characterizes the best-loved urban regions built in the past. The proposed design rules differ radically from ones in use today. In a major revision of contemporary urban practice, it is shown that grid alignment does not connect a city, giving only the misleading impression of doing so. Although these ideas are consistent with the New Urbanism, they come from science and are independent of traditional urbanism arguments.'*

Yet, despite claiming a scientific basis, Salingaros fails to show how this coherence can be measured and, more importantly, fails to present any evidence to suggest that the structural principles have any basis in external reality.

One thing that unifies all of these methods is their designed intention to identify neighbourhoods, rather than neighbourhood places. For example, should we consider a banal suburban neighbourhood as having the same order of place as, say, a vibrant inner city location like Islington? If one was an architect or urban planner seeking to design or redesign a neighbourhood surely these kinds of considerations about the degree of place might be as important as the nature and extent of neighbourhood-place itself. While the neighbourhood identification methods such as Yang & Hillier, Read, Peponis, Salingaros are largely untested, they also largely fail to account for what aspects of our everyday lived experience give rise to these neighbourhood entities. That is, they have no plausible phenomenological basis for their models.

What has arisen is that a number of parties have identified a possible fruitful relationship between the kinds of spatial approaches of space syntax and phenomenological grounding.

Conclusion

The concept of place is a large and rich one. Even after only considering what I have termed neighbourhood–place, it should be seen that the field can only be reviewed in a fragmentary way due to the sheer volume of literature on the subject. One of the important themes that has emerged from this review has been the focus on the debate between place and location (generally termed space and place), which is still an active area of consideration, especially if we consider this a place/space dichotomy. We have also seen that there have been a number of calls to enhance our understanding of place from within the space syntax community, and that a number of authorities see the significance and benefits of expanding space syntax in a phenomenologically grounded way.

Further we have seen that there has been previous research into finding neighbourhoods (see table 2.2) in an objective way, but these have not been tested to any strict empirical test nor do they appear to emerge from any theory which would link back to a plausible theoretical basis for why they identify neighbourhoods, and finally they do not have any linkage to how place might arise in them.

Key points

Urbanisation has proceeded rapidly over the last century and is likely to continue in the next.

Many have charged architecture with creating 'placeless' or 'non-place' locations.

The notion of place has led to a rich body of research in humanistic geography, with emphasis placed on a strong emotional attachment between a place and person.

The concept of place is commonly differentiated from the concept of location by many commentators in the field.

There is considerable debate as to the linkage between place and location.

For clarity, this thesis uses the term space in the architectural sense and uses the word location as a substitute for space as used in the geographic/phenomenological sense.

This gives rise to the question of whether location is neutral and, if it is, is space also a passive neutral component of place?

The architectural theorist Norberg-Schulz bridged the gap between geographic place and architecture by introducing the concept of place having continuity of character.

Lynch extended this notion by introducing the concept of legibility of image, but did not produce a complete objective method with which to achieve this.

Hillier's work suggested that a purely spatial character defined by intelligibility or synergy can define a suitable continuity of character, but the concept is under-developed.

Seamon, Hillier, Sailer, Perdikogianni and others have commented on the potential benefits of creating a phenomenologically grounded extension of space syntax to understand neighbourhood-place.

There have been a number of other attempts to examine the notion of neighbourhood.

The previous works mentioned failed to produce well-founded objective evidence with which to assess the validity of their claims.

Chapter 3: Problem Definition

Chapter Summary

The previous chapter introduced the problem that there appears to be no consensus on the relation between location and place. This chapter forms the core hypothesis for the thesis on the basis that the lack of a clear relation between location and place does not exclude the possibility of one existing. Using the work of Norberg-Schulz (Norberg-Schulz 1976) as a basis, it asserts that place arises from the character, identity or 'spirit' of that space. Given this analogy of character, the chapter goes on to assert that no matter what that character is or how we experience that identity or 'spirit', a place will have to have a continuous extent (homogeneity condition) and its character will have to be different from other places (heterogeneity). The chapter goes on to suggest that space is an under-researched approach to defining our experience of character and that previous research has identified global homogeneity conditions, such as slope of named region correlations (synergy) or the descriptions of neighbourhoods being intelligible or unintelligible (Hillier 1996). It goes on to suggest that local heterogeneity might arise from the local embodied experience of space, from Benedikt's (Benedikt 1979) isovist field via an embodied mechanism introduced by Franz and Wiener (Franz and Wiener 2005) called 'revelation'. This is then reformulated into the basic hypothesis of the thesis: that neighbourhood-place is an expression of the global continuity and unique identity of spaces, at the same time being matched by an absence of local continuity in the spatial visual field, such as that measured by revelation. The chapter then concludes that if objective evidence can be found for the hypothesis, this will support the core assertion that there is a facilitative relation between space and place.

The relation between space, place and location

The literature review in Chapter 2 identified an open question: does place in some way depend upon location or is place just an arbitrary association in the manner of a signifier and significand in semiotics? Clearly, at the lowest level, location is part of place due to the fact that if different geographic locations didn't exist, then all places would be in the same location and it would be impossible to differentiate between them. However, does the physical world we experience make any further contribution to neighbourhood-place?

The work of Langer, as quoted by Relph, appears to be the last word on this. Yet this may be at the cost of trivialising the phenomenological view of space. As mentioned, Norberg-Schultz's (Norberg-Schulz 1976) work is strongly embedded in the work of Heidegger. Heidegger's foundation was that there was no mind-world separation, the mind and world are one, a concept supported by Lefebvre. Heidegger also introduced the concept that space was an a priori concept fundamental to our awareness of the world.

We have also seen that Lynch and Hillier promote the concept of space/volume/void and, importantly, that spaces are interlinked and inhabited. Space in these terms is fundamental and can be experienced in a number of ways (visually, aurally, tactilely...). For example a blind person and a sighted person might have different methods of perception but if they are in a room or a corridor they would both agree as to the kind of space they both occupy. Thus, unlike other perceptions, space can be experienced and shared by both the visually disabled and the sighted. While operating at the level of space, rather than form or location, it is possible to create a shared representation across a number of different perception ranges.

Consider the Langer ship argument for a moment. While the ship moves, the integration and configuration of space remains a near constant. While being location-less, an Ocean liner reinforces social class boundaries, for example by having first and second class decks or in distinctions between passengers and crew. It is known that in many indigenous camps, while not being attached to a specific location, the spaces may have rules. For example, in some Native American camps, the chief lived next to an open area in the middle and the higher status persons lived closer to the centre than the lower. Thus, while the location might change, the spatial structure would have patterns or orderings maintained by the society (the campers). If we consider a city as moving in a geological way, we can see that this movement does not grossly change the relations or volumes between buildings and that the space is constant even when the city is not.

When an urban network or building network changes significantly, it seems necessary to say that the place is changing. The case of Berlin pre-war, pre-wall, with-wall and post-wall seems to suggest that Berlin as a place changed radically. As we experience a connection by moving from one to another we experience the city as a city of flows, the place ballet as Seamon calls it (Seamon 1985). While the geographic location may be slowly moving on a ship or even in a city the habitual routes appear experientially unchanging. Thus, while place may be unrelated to location, the question as to the relationship between space and place is open. If we recast the place location question as the place relation to space, then we need to find aspects of the neighbourhood-place that are structured by space.

Norberg-Schultz (Norberg-Schulz 1976) introduced the use of the human analogy. This is place as a person, a concept captured by the term *genius loci*, the spirit (divine incorporeal person) of a place. This concept goes back to the Romans, but has emerged in many primitive and not so primitive cultures, such as the Arthurian legend of the lady of the lake, that is a spirit of a lake. Clearly, we can be attached to a place in a way analogous to being attached to a person. We can take this further by asserting that a place has character, that is, it has some distinctive and individual qualities. As Norberg-Schultz says, ‘A place which according to local circumstances has a particular identity. This identity or ‘spirit’ may be described by means of the kinds of concrete qualitative terms Heidegger uses’ (Norberg-Schulz 1976). Fundamentally, this requires that one place needs to be separate and distinguishable from another place. If we cannot differentiate between two different adjoining places, then they merge and become the same place.

Yet, this introduces two counterarguments. Clearly, if we create a number of walled communities, we should then create ‘place’. When we do this, we appear instead to create gated communities (Blakely 1997) or the kinds of suburban sprawl that were critiqued as ‘placeless’ in the introduction. We are then left with the proposition that place is related to how much uniformity exists in relation to the whole (or at least the surroundings), the global with the local, as Hillier would say. A neighbourhood is created by how place is connected to the larger urbanity rather than whether it is connected. Neighbourhood exists because of, not despite, the ‘fuzzy boundary’ that it possesses.

This leads to the second problem, which Norberg-Schultz called the identity of a place. Talen (Talen 1999) relates a story about how some planning systems have regulations that forbid differences for the sake of visual community cohesion and others that regulate over-similarity for the same reasons. If place exists through any uniformity (presumably in space), then all places are equal. Yet as Webster points out (Webster 2003) all neighbourhoods are not equal; a neighbourhood in suburbia is different from a neighbourhood in the centre of the city. Camden or Hoxton in the city of London is different from Hampstead Heath and we can feel this upon exploring a place. So while the uniformity of global relations defines the extent of a neighbourhood-place, perhaps local factors define the nature of its character.

More prosaically, we can make a number of observations about place. First, you cannot be in two places at once; that is, while places lack precise edges, they do exhibit continuity. So, you cannot move from Camden to Islington and then find a small zone of Camden embedded within the middle of Islington. If we did find a kind of archipelago of neighbourhoods, we would intuitively find this quite strange. This appears to limit our sense of neighbourhood-place. However, places can be nested within each other. So Camden or Islington can be within the city of London, which is in the south-east region and within England, and so on. But notice that this nesting implies general containment: a neighbourhood-place can be in a city but infrequently, in common use, can it be in two cities simultaneously. Finally, a place has to be the same as itself; it has to have some local homogeneity. Yet, one place must have a different character or *genius loci* from another. Places must exhibit heterogeneity; they must be different from each other. Clearly, at the lowest level, if there is something about a place that exhibits character, then that character must be different from another area. Otherwise, we would expect the two areas to merge together. Without saying what it is from our embodied experience of a place that we might be using to identify it as a place or how we are cognitively processing this information to arrive at our sense of place, we can intuit that place has a number of essential traits that have to be satisfied, no matter which mechanism we choose to objectively define place.

Notice from this, that the problem of planning for over- or under-uniformity becomes clear. If we have an extreme degree of heterogeneity (all of the buildings look different), then it becomes hard to think of the area as a coherent neighbourhood; we have noise in the information sense. If we have a complete uniformity of buildings (each building being an identical copy of the next in some suburban development), then we have no signal in the information sense.

Thus, while we have not seen what place is, we can identify two primary conditions for what a place might be.

The essentials of place

We may conclude that place is based on two fundamental aspects.

Homogeneity: The first is that a place must have some continuity of character that would lead one to associate a set of locations (or a space) as one 'place'.

Heterogeneity: Second, we must experience some local variation within that continuity to give the place the kind of character that differentiates one place from another.

From the reasoning given in the previous chapter, one candidate for the basis of that character that has not been given much attention is the nature and configuration of space. For this reason, this thesis explores the issue that space contains empirically identifiable imprints that afford the nature of neighbourhood. That is, while neighbourhood is a social thing, it responds to the affordances that space gives to it. As such, we might find that space affords a neighbourhood that is not permitted to be, just as an abandoned village affords the possibility for a village or settlement but does not demand or cause it.

An analogy might be helpful at this point. If we looked at a field in the countryside, we might see a field of poppies next to a field of buttercups. The patchwork of poppies would appear distinct due to homogeneity; since the poppies are similar to each other, we don't see them as two patches of poppies side by side with no gap between (if we did then why not three or four…). Equally, heterogeneity means that we see the field of buttercups as a distinct and separate entity due to the differences between buttercups and poppies. If the differences between the poppies and buttercups were too small (if both flowers were orange for example) to distinguish, then, due to the rule of homogeneity, we would have to see them as one large field. These then are two fundamental rules that define the basic conditions for identifying two or more entities, which must be co-present when we experience them.

If it was possible to find aspects of space that are interwoven with the social neighbourhood-place, then the first question of whether there is any relation between space and place will have been answered.

The space of place

Perhaps to recognise where we are, and to do so immediately, we might need to have a number of parallel levels of consideration. We have already seen from the work of both Lynch and Hillier that we have local visible cues to the local environment, and we appear to have some kind of mental representation that works with these environmental cues. Penn (Penn & Dalton, 1994) proposed that humans cognitive capacity may be at least in part in the form of a 'correlation detector' perceiving local spatial properties and using them to predict global properties. This world that is known but cannot be seen is what appears to be at the heart of legibility, intelligibility and synergy. Read (Read 1999), the creator of the average integration measure, talks of local grids and super grids.

At the visual level, when considering what Montello terms the 'gestalt' of layout, we have the concept of the isovist, the visual field around us. The concept of the isovist was introduced by the architectural theorist Benedikt (Benedikt 1979) as a horizontal two-dimensional slice through space, typically taken from eye height, of the three dimensional view seen by Hardy (Hardy 1967) and discussed by Tandy (Tandy 1967), as a method by which to measure the visual spatial properties of an architectural environment from one point. This may have been seen as a simplification of the geographical, archaeological and military concept of the viewshed of all the surfaces visible from one point. It is the attempt to give the location of the centre of the isovist properties, generally derived from the morphology of a two dimensional polygon of the isovist, that distinguishes the use of the isovist from the viewshed. These properties include area, perimeter, the second moment (variance) of the isovist boundary and the third moment (skewness) of the isovist boundary. Benedikt differentiates between rays that intersect some occluding surface and those that are tangential to the edges in a room. Benedikt sought objective methods to combine experience and the morphology of a room into an analysis.

Work on isovists has recently continued, such as by Turner (Turner et al. 2001), who introduced the concept of a visibility graph for an isovist field or a lattice of isovist points. With this, he also introduced the concept of forming a graph by examining the intersection of isovist points and then using them in a syntactic analysis of the resulting graph. Turner's work showed a high correlation between the movements of visitors to the Tate gallery and the measurements of isovist integration. With this work, he effectively merged the local scale (the scale of the body and the view from the body, along with a survey taken by the eye) with the global (the world beyond the immediately visible, the gallery in the mind). Conroy (Conroy 2001) introduced the concept of the partial isovist (what Montello called the vista) as an isovist limited by the field of view from one point. Here, we see the accidental flow between the pure spatial measure of a building and the more specific model of an inhabitant. The pure isovist is a measure of a building's space from a point. The partial isovist or vista is dependant upon knowing the direction and field of view of the individual (real or presumed). Further work by Conroy Dalton and Dalton (Conroy Dalton and Dalton 2001) introduced new concepts, such as drift (the vector difference between the centre of the generated isovist and the centre of gravity of the resulting polygon). Further work by Franz and Wiener (Franz and Wiener 2005) introduced the concept of revelation, the sum of all the possible changes as one moves from one point to all of the other surrounding points in a regular lattice of isovists from the starting point. Their work suggests that our appreciation of the world is measured by the isovist. In their test, participants that were asked to find the best place to hide tended to find the point in space with the smallest isovist.

It seems sensible then to suggest that there are two (or possibly three, depending on the definition) uses of space at different scales, the global super space – the familiar highways and common routes, the routes into and out of a community, and the local place or local space that can be walked to but cannot immediately be seen. Finally, there is the super-local, the world that is apparent to view in a particular time and space; this is the world common to Golledge (Golledge 1995)(Golledge and G. 1976) and environmental psychology.

This local visible path-based change in the visual flux could potentially be the result of a number of other types of changes. For example, it might possibly be related to changes in the textures of building materials or colours or sounds. We have already seen that the participants in the Lynch survey created the element of the landmark or visual indicator. As such, we might suppose that Lynch's (Lynch 1960) mental map is a fusion of the global (district, edge) and the visible local (landmark, node). One possibility for a purely objective measure of the super-local vision of space is the previously mentioned revelation, the change in the visual field around the pedestrian. From this point of view, we might regard a walk through an underpass or down a long corridor as a path of minimal change in the isovist or as a minimal revelation path. If we walk in a forest for the first time, the isovist spaces appear to change randomly, creating a sense of disorder. Perhaps the human mind, having evolved in these conditions, might adapt, but it is also known to be hard to maintain orientation in a forest. As such, random changes in the isovist might well be hard to remember. As we move through an urban environment, we might find the journey interesting, having an intermediate change in revelation. That is, an intermediate between no change and random change. Perhaps, as Montello suggests, this might be related to the relationship between the view of information and the entropy of the passing data (Shannon and Weaver 1949)[1]. The revelation along a notional path, having no change relates to no change in information and an absence of stimulation. Equally, when there is no perceptual pattern to the random changes in an isovist, the informational content of the path is also near zero. It is only when there are information patterns in the information changes of the isovist that we might conceive

Local continuity \ Global continuity	HIGH	LOW
HIGH	A	B
LOW	C	D

Table 3.1 Global and local continuity

1. Shannon was a theoretical engineer, mathematician and the first information theorist. He was interested in the limits to the capacity to send information over a medium, such as an electrical signal cable. As such, he became interested in the complexity or interestingness of a message, especially when that message could be compressed. For example, the pattern 11110000 could be reduced to 4 x 1 and 4 x 0 (a savings of 4 or 50% of the data elements). The pattern 101010101010...1010 could be reduced to 40 x 10. But the random noise from an un-tuned radio could not be reduced to anything less than itself. Shanon introduced the concept of entropy to measure the rate at which information could be compressed and then transmitted. Thus, both a constant pattern (1111) and a random pattern have low entropy, but a complex pattern has a high degree of entropy.

of a local perceptual field as being interesting (having high entropy) or memorable.

Place can then be hypothesised as a contraction of two types of space. We begin with the objective notions of Hillier (Hillier 1996), that of place as a continuity of identity or spatial character; a vibrant place then is one that has a spatial character that is different from that of the surrounding settlements. Being spatial, that neighbourhood-place character is maintained despite changes in the building fabric. This continuity reflects its nature in synergy, intelligibility and average integration. We also operate in a second space, a more direct bodily space, such as that of the isovist. This bodily space can change as we move through space or revelation. While a viable place must maintain a broad character and continuity of identity, the local bodily space is the reverse; this requires that space to have high entropy. Again, both degrees of observational limitations apply. If the person cannot perceive the changes, then the changes are not significant and have no value.

From this, we can set up a matrix of potential spaces that can be used to explain the possible results.

Space A has a high degree of local continuity and a high degree of global continuity. This might be a uniform area that is different from the surrounding neighbourhoods but is also uniform at the perceptual level.

Space B has a high degree of local continuity but a low degree of global continuity. For example, this might be an area where a number of spatial mixes have been placed close together but locally there are no significant changes; for example, a housing estate where the buildings are identical but some are grouped into a close, others a square and others into streets.

Space C has a high degree of variability but a low degree of global continuity. For example, this might be a village like Corbridge or Loughton in Milton Keynes, or an area like Camden in London, or Inman Park in Atlanta.

Space D has low global continuity and low local continuity. This might be a space that has no clear linkage to or from other spaces. Equally, the local buildings appear to be orientated randomly. An example might be a sprawl district with a number of dissimilar houses.

Thus, we come to the conclusion that there is a potential hypothesis for place. This thesis asserts that place involves an emotional attachment to a group of locations and that this group of locations has two parallel aspects. First, that the place is identifiable and unique; to use the Norburg-Schulz term, it possesses character or an identity. To be unique, a neighbourhood place, for example, would need to be differentiated from the surrounding urbanity and yet consistent within it. This consistency is at the global scale and is hypothesised to be a function of the spatial continuity beyond the current point of reference. Due to the global nature of the consistency, this must be a conceptual consistency, a continuity held in the mind. Given that the neighbourhood lies beyond the immediately perceivable, the consistency involves how the urban landscape is conceived. One powerful example of this consistency is given by Hillier and termed intelligibility; a second one suggested is that of synergy, also by Hillier. For place to be present, it is hypothesised that global continuity by itself is insufficient to achieve this goal. To achieve this, the hypothesis asserts that a second scale is needed, that of the body space. For the body scale, it is asserted that perceptual continuity produces uniform environments that make navigational functions, such as orientation and location, difficult to perform reliably.

This thesis suggests that while attention is and should, according to Montello, generally be applied to visual stimuli (the elevation, texture, colour and so on), the use of space at a level of fine granularity has been under-researched as a way of adding variety, texture and recognisability to location and movement. Uniquely in this context, this thesis proposes that local spatial complexity is of itself sufficient to guide the recognition process. It should be acknowledged that other forms of identification may augment the recognition process, but uniquely, space, being an a priori concept, can subsume them. This thesis asserts the hypothesis that space alone is capable of forming local patterns that can be used in the recognition process and, as such, in the formation of the spatial underpinning of a social place.

To this end, the thesis proposes that changes in the local isovist field, called revelation by Franz and Wiener, may be enough to situate the inhabitant in a space. A well formed place in this hypothesis requires that space be both meaningful and recognisable. To this end, it is suggested that the informational changes in revelation determine the difficulty of identification. For example, changes in a revelation flow that has no changes or only random changes would be difficult to recognise.

To restate the core hypothesis then, the problem that this thesis seeks to explore is the evidence for any relationship between the physical world and place. Place, it is asserted, arises out of two necessary conditions (given above as the essentials of place). This thesis explores the possibility that these two aspects can both be based in space (but not necessarily location).

Summary of the place hypothesis

The hypothesis is stated that place or neighbourhood place is based on two factors.

Neighbourhood Place is an expression of the global continuity and unique identity of spaces;

At the same time being matched by an absence of local continuity in the spatial visual field such as measured by revelation.

If these appear to be correct, then the more fundamental hypothesis that place is related to space, rather than location, appears also to be substantiated. Or, more specifically, it will contradict the assertion that space has no relationship to place, i.e. that place is a purely social concept unrelated to the physical environment.

Key points

- The question of the strength of the relationship between place and location remains open.
- If we think of space rather than location, the Langer objections to the relationship between location and society no longer appear to apply.
- Norberg-Schultz introduced the concept of place having a character than can be appreciated in some way, suggesting that it is the distinctiveness of a location that gives rise to the sensation of place.
- At the most fundamental, place must exhibit two primary qualities:

- **Homogeneity: The first is that a place must have some continuity of character that would lead one to associate a set of locations (or a space) together as one ‘place’.**
- **Heterogeneity: The second is that we must experience some local variation within that continuity to give the place the kind of character that differentiates one place from another.**

Space appears to be an under-researched method for understanding how place might be partly embedded in the physical fabric around us. Space appears to be part of what Seamon calls the place-ballet influencing the flows through a city.

Hillier introduced the concepts of intelligibility and synergy as properties of an area related to how one conceives of a space.

Franz and Wiener, following Benedikt’s (Benedikt 1979) work on isovists, appear to associate our experience of space with our local perception of space as we move through it via a measure called revelation.

This leads to the place hypothesis:

Neighbourhood Place is an expression of the global continuity and unique identity of spaces;

At the same time being matched by an absence of local continuity in the spatial visual field such as measured by revelation.

If these appear to be correct, then the more fundamental hypothesis that place is related to space rather than location appears also to be substantiated.

Chapter 4: A Brief Introduction to Space Syntax

Summary

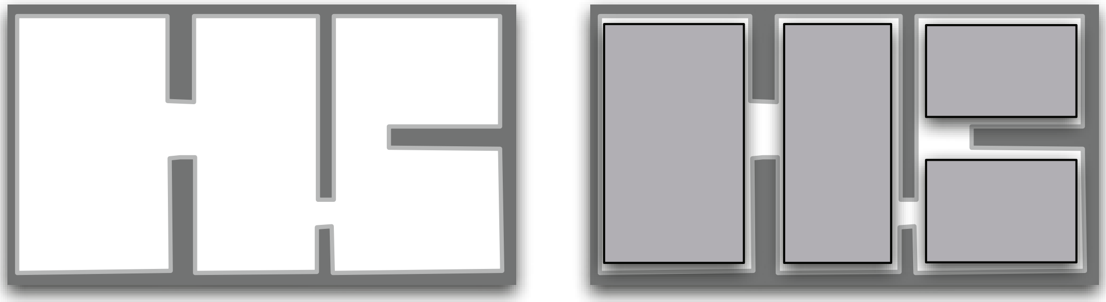
This chapter introduces space syntax theory, or the portion of it that is relevant to this thesis. The fundamental breaking up of a system into component spaces is introduced. From this point of view, it is possible to consider a region as a group of interconnected spaces. Two methods for performing this spatial break-up are introduced: axial and isovist representations. The chapter goes on to show how these are processed and gives a demonstration of the utility of space syntax as a tool to understand pedestrian movement. The chapter shows how intelligibility and synergy, terms introduced by Hillier, are computed and interpreted. The chapter reviews segmental and angular methods and shows that it is currently unknown how to compute synergy and intelligibility in this segmental context. Given the basis of this thesis in intelligibility and synergy, it is then concluded that an extension of this work into the new segmental representations will have to wait until sufficient development work has been done in this area, and so it is excluded from consideration in this thesis.

Space syntax

One of the core aspects of this thesis is that one under-explored aspect in the discussion of place is the role that space may have in its production and formation. One of the primary theories in this area is called 'space syntax'. Given the importance of space syntax theory to the investigation of place that is used in this thesis, this would be an opportune time to introduce relevant aspects of the theory.

It would seem necessary to introduce the basis of space syntax analysis before it is applied to a case study. Space syntax is the name given to a body of theory and analysis broadly looking to understand the role of configuration in a built environment when considering social aspects of the built environment, such as inhabitation, crime, social encounters and social interaction. The core work of the theory was produced by Hillier and Hanson (Hillier and Hanson 1984) (Hillier and Hanson 1987) (Hillier and Penn 1991) (Hillier et al. 1993) (Hillier 1996). The field is constantly and rapidly developing, but might be summarised as follows: Space syntax promotes the concept that permeable space should be the fundamental unit of analysis when considering the social function of a building. Permeable is a relative term - a river is permeable to a boat or a swimmer but is an impermeable space for a bus, car or typical pedestrian. The notion of permeability then depends upon the mode or modes of transport considered. It is also necessary to understand which spaces are generally permeable (accessible); for an urban environment, it is generally possible to consider all buildings as impermeable.

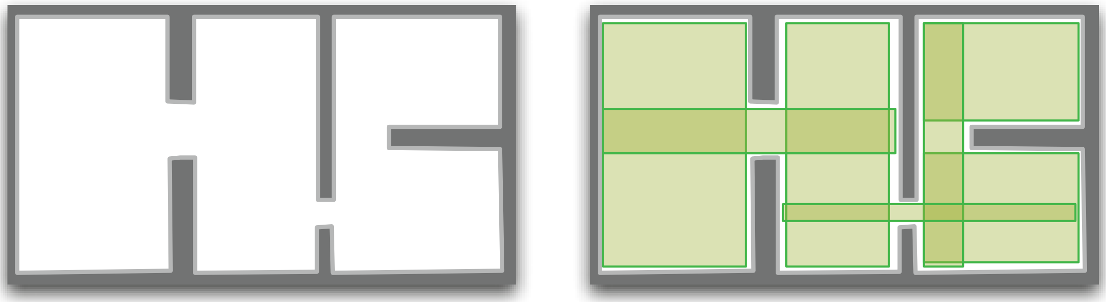
A space syntax analysis begins with the production of permeability maps for a system (building, village, town, city). To begin, all of the spaces are identified. The specific meaning of a space



Building outline in a plan

Non-overlapping convex spaces of a building

Figure 4.1 A building plan and non-overlapping convex spaces of a building.



Building outline in a plan

Overlapping convex spaces (green)

Figure 4.2 A building plan and overlapping convex spaces.

depends upon which spatial decomposition was chosen. For example, spaces can be broken up into rooms or convex spaces – a common method in buildings. Urban systems can be decomposed into ‘axial lines’, which are ‘the longest lines of sight that fully describe a system’ (Hillier and Hanson 1984). Other descriptions include a grid or field of points linked by intervisibility, such as an isovist-grid ((Benedikt 1979) (Penn et al. 1997) (Turner and Penn 1999), continuity lines (Figueiredo and Amorim 2005) or line segments (Peponis, S.N. Dalton and R. Dalton 2003) (Hillier and Iida 2005).

Convex space descriptions

At the building level, the notion of ‘space’ becomes rather synonymous with the concept of room. The concept of a convex space is a highly embodied concept, a space becomes an occupiable void, where if two people can see each then in a convex space a third party that can see the first can also see the second. This mutual co-visibility suggests that convex spaces are linked by conversation and so occupation. Convex spaces come in two species. The first is the non-overlapping convex space partition, where each space can only be adjacent to another space (see Fig. 4.1 above).

Overlapping convex spaces (see Fig. 4.2 above) presume that sometimes a point can be in several spaces at once but that all of the spaces are defined in some way by a surface (as a common example, a wall). Interconnection in this case is by special connectors (such as doors) or overlap, and in a fractional case by the degree of overlap.

Isovist

The isovist, first introduced to the architectural field by Benedikt (Benedikt 1979), is a planar

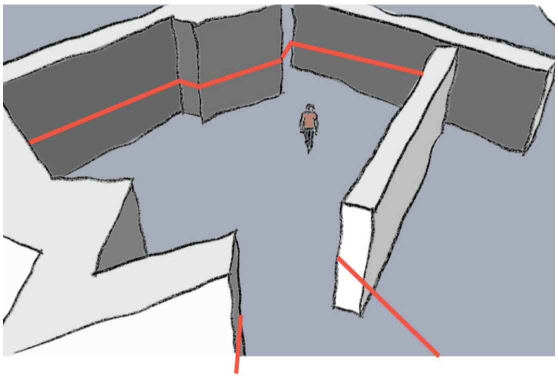


Figure 4.3 View of isovist (red line) from eye point of inhabitant.

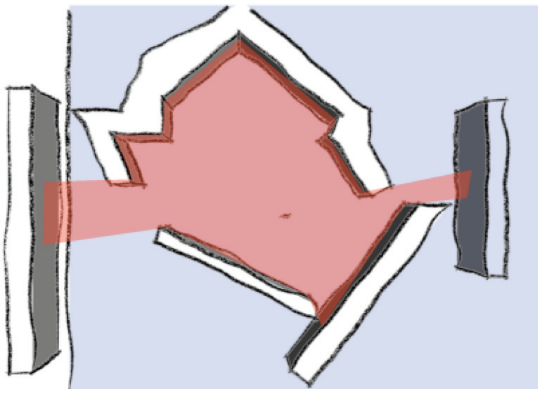


Figure 4.4 Plan view of isovist (red region) from eye point.

polygon in a plan that describes the limit of the view-shed or field of view for a single static viewer (red in Figs. 4.3 and 4.4 above). If one imagines a ray proceeding from the eye, then the point of first intersection with the first occluding object defines a point in space around the observer. By measuring the properties of this polygon, it is possible to make assertions about the nature of the space. For example, a large area implies a certain degree of spaciousness and a relatively small isovist implies that of compactness or enclosure. Values such as the area to perimeter ratio indicate how circular or 'not spiky' a space might be.

While it is possible to make statements about specific locations using basic isovist measures, it is also possible to make repeated

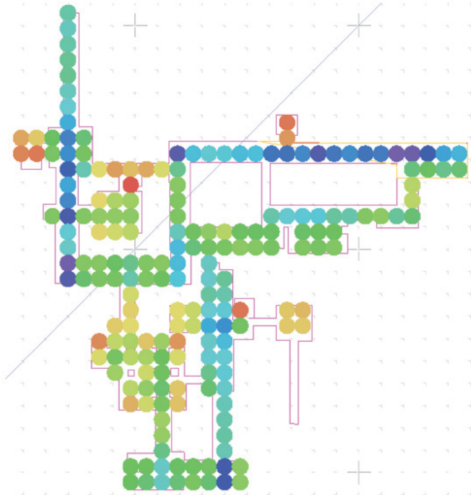


Figure 4.5 Gridded isovist after Turner (Turner and Penn, 1999).

isovist measurements using a regular grid. While informative, these are still simple metric measurements of space. One innovation introduced by Turner is that of the isovist intersection. If the polygons describing two isovists intersect, that is, if the centre of one isovist lies within the isovist of another, then it is possible to move from one point in space to another. This implies that if it is possible to move from one isovist space to another, the two spaces are 'connectable' in some way. Thus, it is possible to create a graph of the interconnection of isovist spaces by checking the intersections of each isovist with every other isovist. While the nature of these graphs differs from that of axial graphs, it is possible to perform the same kind of analysis as described below. By nature, a gridded isovist analysis (Fig. 4.5) is large and overly detailed at the urban level. Isovist analysis comes into its own when looking at finer details in the interaction of a smaller scale space with its occupants.

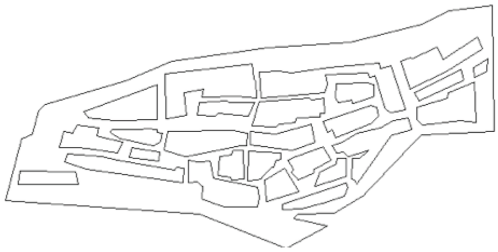


Figure 4.6 Gassin - village map (Hillier and Hanson 1984)

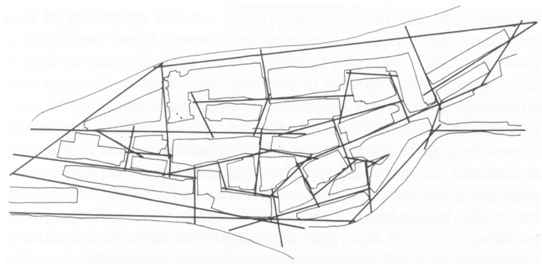


Figure 4.7 Gassin - village map with axial line spaces (Hillier and Hanson 1984)

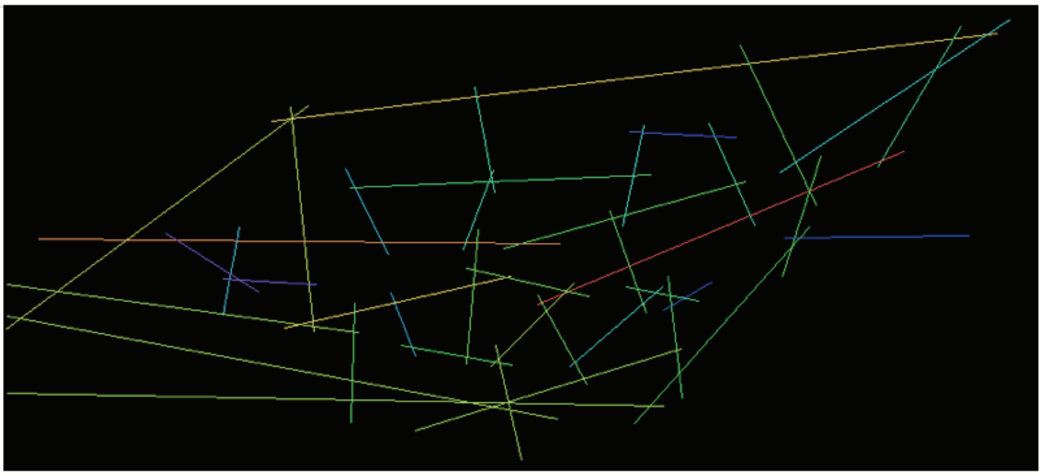


Figure 4.8 Gassin - village map with axial line spaces by integration.

Axial line descriptions

An axial line attempts to describe the longer, more axial spaces found in urban systems. An axial line map is frequently described as the smallest set of the longest lines of sight that fully penetrate (cover) the map in question. The axial line description is primarily a long line of sight in the plain of the observer or inhabitant of the system. This spatial representation reflects the highly linear movement found when traversing through the public space in an urban or suburban system, typically roads and streets. The construction of an axial map is presented in Figs. 4.6, 4.7 and 4.8 above.

Segmental

The segmental description (N. S. Dalton, Peponis, and C. Dalton 2003) (Hillier and Iida 2005) can be seen as an extension of an axial map, that is, when an axial line intersects another,

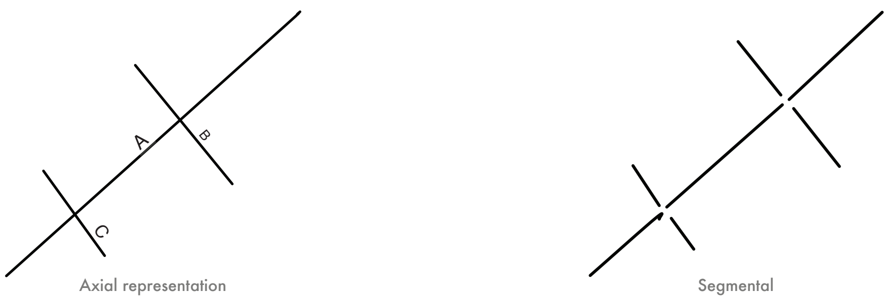


Figure 4.9 Axial and segmental representations.

it can be considered as starting a new segment (see Fig. 4.9 above). This representation has been regard as more ‘primal’ but this may be due to its common use in graphic information system representations of road centrelines. One important difference between this and the transport engineering approach is that the traditional transportation description regards intersections as nodes and streets as edges. The segmental approach maintains the supremacy of conceptual complexity by using a node as a segment (street) and an intersection as an edge. Technically, one is the edge of the vertex dual of the other but the segmental description implicitly promotes the concept of intersection angle, whereas the traditional transportation approach promotes that of the metric distance between nodes.

Segmental processing is a relatively new form of spatial representation with work still needing to be done in a number of ways, which will be described later.

Graph theoretic processing

Once a permeability map has been decomposed into a discrete set of spatial units, the intersections of these spatial units are used to create a secondary representation in the form of a graph. The process of intersection can be discreet (connection or no connection) or continuous, for example the angle of intersection or area of overlap discussed by Dalton (N. Dalton 2001) (Turner and N,S, Dalton 2005). Conceptually, we can consider an axial line as a unit of conceptual complexity. In other words, remembering the same direction is simpler than remembering a number of twists and turns, as shown by Conroy (Conroy 2001) and Penn (Penn and N. Dalton 1994).

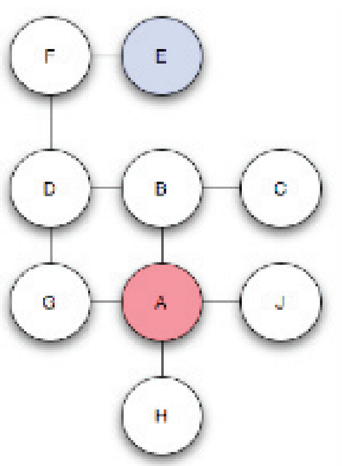


Figure 4.10 A simple graph of the connectivity of rooms in a building.

Considering the simplest discreet case first, we can see that a simple building can be viewed as a graph (Steadman 1983) (see Fig. 4.9). The graphs used by space syntax typically have bidirectional links (if you can leave A and step into B you can turn around and go directly back to A) and are fully connected (it is possible to go from A to every other node in the graph). Graphs tend to have simple sets of predicate qualities – is the graph connected, is it Hamiltonian, is it planar, is it small world; they can also have gross measurements, such as the size, edge count or girth. Space syntax differs from standard graph theory by being interested in each node and the relationship between each node and the entire graph, something only generally studied in social networks. An example of a property of a node is that of its connectivity or degree. In other words, how many connections are made from this node to the other nodes in the graph (in Fig. 4.1 E has a connectivity of 1 and A has a connectivity of 4). One property frequently referred to in space syntax is integration.

To demonstrate the concept of integration, consider the graph in Fig. 4.10. We begin by considering the graph from the point of view of node A. We build a j-graph or shortest path tree (Harary 1959)(Buckley and Harary) from node A. Each node is then labelled with the shortest distance from node A. For example, H is at depth one and E is at depth four from A. Notice that the concept of shortest distance ignores the actual path from A to E (A,G,B,D,F,E or A,G,D,F,E). For the informed but uninitiated it is sometimes counterintuitive to realise that the total distance from A to every other node in the system is or can be different from that of E. The concept of total depth is equivalent to the concept of status for Harary (Harary 1959).

We can calculate a mean depth value by dividing the total depth from a node by the size of the system. To counter this, it is possible to use a system of relativisation equations to compute the Relative Asymmetrical depth (RA) and Real Relative Asymmetrical depth (RRA); see (Hillier and Hanson 1984),

Dij = shortest step depth from node i to node j.

For a connected graph with N nodes, the total depth D can be found by Equation 4.1:

$$T_i = \sum_j d_{ij}$$

Equation 4.1

The mean depth for node I is defined by Equation 4.2:

$$\mu_i = \frac{T_i}{N-1}$$

Equation 4.2

Relative asymmetry tries to normalise the mean depth between the limits of the unit sequence (longest) and the star (shallowest possible configuration) in Equation 4.3:

$$R_i = \frac{2(\mu_i - 1)}{(N-2)}$$

Equation 4.3

The real relative asymmetry = RA ÷ D, where D is the D-value equation for a system of size N. See Equation 4.4.

$$D_n = \frac{2\{n[\log_2((n+2)/3)-1]+1\}}{(n-1)(n-2)}$$

Equation 4.4

Taking the reciprocal of these depths, we can compute the value of integration in Equation 4.5:

$$I_i = \frac{D_n}{R_i}$$

Equation 4.5

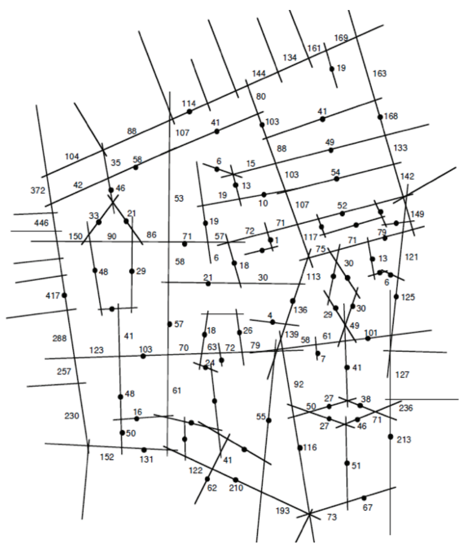


Figure 4.11 Barnsbury pedestrian observations (Adults/ph) www.spacesyntax.org/publication.

Other forms of relativisation are also possible, such as those described by Teklenburg (Teklenburg, Timmermans and Van Wagenberg 1993). The above form of relativisation makes the implicit assumption that nodes are either connected or not connected. The trend in the field of space syntax is to move toward an angle-based measure of depth; these values can range from 0 to 1 or 0 to 2. The standard forms of relativisation are unsuitable at these levels and need to be replaced with something more suitable; see the work on vicinity (N.S. Dalton 2005) (N Dalton and R. Dalton 2007).

Visualising these values back on the original axial map, it is possible to colour each line by a colour taken from where on the spectrum the value lies. So, the highest value of integration (lowest value of mean depth) is red and the values decrease through orange, yellow, light green, dark green, light blue and finally dark blue for the lowest integration (largest mean depth). Areas that are in the red/orange colour (high values of integration) are typically described as integrated. The usage of the word integration reflects the common usage of the term integrated over the mathematical usage.

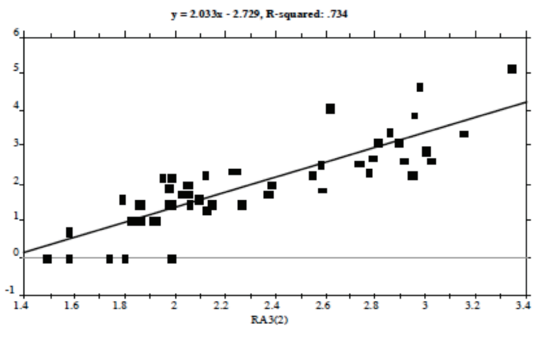


Figure 4.12 Correlation between local integration and pedestrian movement for Barnsbury; source (Hillier 1996).

*'The action or process of integrating: economic and political integration | **integration** of individual countries **into** trading blocs. The intermixing of people or groups previously segregated: integration is the best hope for both black and white Americans.' (New Oxford American Dictionary)*

Areas of low integration (blue) are termed segregated, that is, cut off from the surrounding territory. For many typical urban environments it has been found that areas of high integration correspond to the busy areas of a city, with the most integrated lines frequently corresponding to the central or most economically active areas of a city. For example, in a map of London, Oxford Street emerges as the most integrated street. Highly cut-off locations (back alleys, cul-de-sacs) tend to be more segregated (low integration). Previous research has shown that if the pattern of pedestrian movement is recorded (by counting the number of pedestrians passing a notional gate) (see Fig. 4.11) and compared to the axial integration values, the pedestrian flows tend to strongly correlate with integration values (Hillier et al. 1993); see Fig. 4.12.

Note that in this form of analysis, the only input to the 'model' is the configuration[1] of the space. This analysis does not include attractors (shops, offices, restaurants) or generators (train, tube or bus stations, parking lots). Neither does the analysis include land use patterns, road quality or the 'mental models' of average pedestrians. This minimal input modelling makes syntactical analysis very suitable for early-stage conceptual design. It has also been used by archaeologists trying to investigate the use structure of the remains of settlements.

1 A configuration is defined as a set of spaces and spatial relations where each space affects and is affected by all others; a change to one space will ultimately produce a change to the status of all other spaces.

Figure 4.13(a): Barnsbury axial map radius global (infinity).

Figure 4.13(b): Barnsbury axial map radius 3 integration.

Radius

For villages and towns, the concept of integration is frequently all that is needed to perform a syntactical analysis. For larger systems, such as entire cities, the implicit assumption that it is possible and likely for pedestrians to consider a trip from any origin to any destination breaks down. To allow for this, space syntax introduces the concept of 'radius', which is a limit to the topological (step) distance that is considered. For example, we can create a window that is radius 3 (three steps) from each axial line and only consider the space within that subset or locality of a city. This concept of locality will be returned to in later chapters, so it is preferable to fully explain it now. By limiting the area of consideration to three steps, we have the locality that is more likely to be used by the pedestrian. To quote Hillier,

> *'local integration in urban systems is the best predictor of smaller-scale movement - that usually means pedestrian movement because pedestrian trips tend to be shorter and read the grid in a relatively localised way - while global integration is the best predictor of larger-scale movement, including some vehicular movement, because people on longer trips will tend to read the grid in a more globalised way. ' (Hillier 1996, 99)*

Consequently, the global movement pattern described initially can be referred to as radius infinity, or historically radius-n. The mode of transport was mentioned initially as one of the key factors for understanding a permeability map. It has been found that differing radii are also useful in understanding movement patterns. For many cases, in many cultures and geographic locations, pedestrian movement is found to correlate well with values like radius 3 (see Figs. 4.13a and b). For vehicular transportation, larger radius values are appropriate to correlate and predict the observed movement patterns (Penn et al. 1998).

It is likely that a differing number of nodes will be found within a radius. The values of the mean depth within a limit (say up to 3 steps away) can approach a constant (N.S. Dalton 2005), that is the correlation between the number of lines encountered and the total depth within a radius can correlate highly (0.99 being typical). Fortunately, in these circumstances, the relativisation equations introduced above for topological axial graphs can be applied to bring the values back into comparability.

Choice

The concept of choice has been present alongside that of integration for many years in space syntax. The measure of choice is strongly reminiscent of the betweenness concept of social network theory (Freeman 1977), but is computed in a slightly different manner. The algorithm works as follows[2].

Each origin/destination A,B ($A \in G$) ($B \in G$) pair is considered.

All of the shortest routes from A to B are considered.

A conceptual agent with a weight of 1.0 is sent to traverse the route from A to B.

At each stage, the agent applies its weight to an accumulator belonging to each axial line.

The agent then moves to the next closest node in the graph towards B. If there are two similar shortest routes, the agent is divided in two and

2 This algorithm is simple to perform on a true graph representation. Betweenness counts the maximum number of paths from A to B and distributes agent weights evenly over the maximum paths. This is simpler to compute using a matrix representation, which is acceptable when dealing with small non-urban graphs.

Figure 4.14: Barnsbury axial map logarithm of global choice.

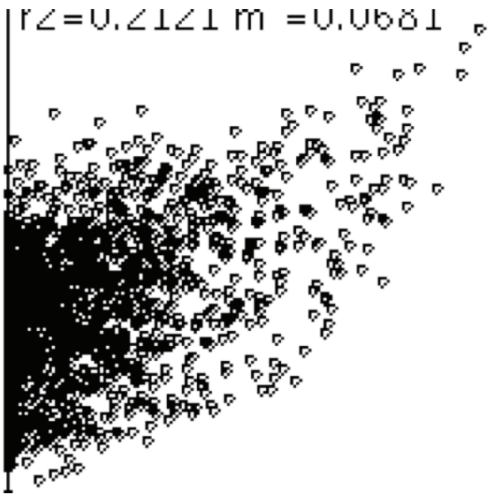


Figure 4.15 Scattergram of Barnsbury with integration on the vertical axis and the log of choice on the horizontal axis, R2 = 0.21.

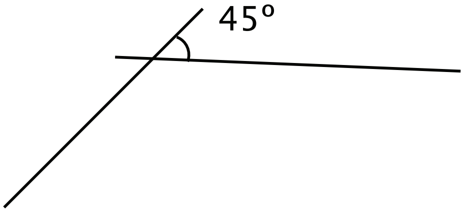


Figure 4.16 Angle of axial intersection.

each sub-agent takes its respective fraction from the weight of the original agent.

The two routes for the two sub-agents connect later, the sub-agents join to form a sur-agent and the weights of the sub-agents are summed.

This process repeats until the agent or all of the sub-agents reach the destination pair.

One of the main advantages of this model is that it provides a simple cognitive model for how an urban movement pattern emerges, a model which is absent from the integration measure. Such a model could be described in a simple way, as follows. The city can be considered as having a large population that is concerned with moving from any building to any other building. Each inhabitant considers the simplest cognitive model distance from their current location to their intended destination. Where there is more than one choice which are equally short, then half of the population will take one direction and half of the population will take the other. At each street or axial line we station an observer. This observer counts the number of people passing them at that point, which becomes the value for the axial line (see Fig. 4.14).

Generally, the choice and integration values for an urban environment have a strong correlation (see Fig. 4.15 above). It has been found that while the choice measure does correlate reasonably with observed movement it does not correlate as well as the integration measure. Historically, the choice measure has also been far more computationally difficult than the integration measure, which has led to the preference of using integration rather than choice. Recently, with the rise of much faster processing and, more significantly, the rise of angular based measures, choice has been found to provide a better segmental representation of movement than that provided by the integration measure.

One observation about choice, which will be relevant later, that was made by Peponis (Peponis et al. 1988) after studying a group of Greek towns and villages, was that lines of high choice tend to mark the bounds of neighbourhoods.

Fractional or Angular integration

In an appendix of her PhD thesis, which looked at user movement in virtual environments, Conroy (Conroy 2001) introduced a theory that local scale route planning was a ‘matter of following one’s nose’. This begins with the common observation that people can take one

Figure 4.17: Barnsbury axial angular integration.

route to a destination (A to B) and another back (B to A), which might be explained by an assumption of minimum deviance of the angle to the destination. This led both Dalton (N. Dalton 2001) and Turner (Turner 2001) to independently consider that angle might be a more fundamental explanation for the function of an axial line. Dalton, working with axial lines, and Turner, considering isovist grids, asserted that one might consider the graph of interconnection to be weighted. In a typical graph, the connections are either present or not present. Given the emergence of space syntax from the study of buildings, this is not surprising. The proposal was that a graph might have non-negative normalised weights and that these could be incorporated into the syntactical integration model.

Angle °	Edge-value
0	0
45	0.5
90	1.0
135	0.5

Table 4.1 The angle to weight conversion.

In (N. Dalton 2001) Dalton introduced axial angular integration, but as a specific aspect of a more general 'fractional integration', which could be expanded to include other forms of intersection, such as that between two overlapping convex spaces. Axial angular integration was based on looking at the smallest angle of intersection between two lines. Thus, lines that intersected orthogonally had a weight of 1.0 and lines that had a shallow or highly obtuse angle of intersection had a value close to 0.0 (see Fig. 4.16 and Table 4.1). In this paper, Dalton made the observation that angular axial integration appeared to provide incremental improvements to the axial integration model. For example, the global integration and fractional angular axial maps appear to be nearly identical except for a portion of Theobold Street to the bottom right, which shows that the historical meandering route is now far more integrated than before (see Fig. 4.17).

Segmental angular processing

Dalton's axial representation was criticised by Asami (Asami 2003) as being incapable of dealing with angles greater than 90 degrees, which when looking at an axial representation seemed necessary. Peponis and Dalton (N. S. Dalton, Peponis and C. Dalton 2003) then proposed a segmental representation based on a desire to process US TIGER format GIS data. Their primary observation was that if two line segments were parallel and connected, then in the angular method of representation they could be considered as having zero depth. If an axial line was replaced with a number of segments, then the depth gain 'along' the segment could be considered to be zero, making a line of segments behave functionally like a 'virtual' axial line. Recently, this concept has been developed by Figueiredo (Figueiredo and Amorim 2005) to form a super axial line, which is capable of representing a 'non-straight' axial line.

Hillier and Iida (Hillier and Iida 2005) developed this concept by considering that such a representation could handle the problem of angles greater than 90 degrees. Hillier and Iida were also the first to test this measure and show that it appeared to provide a more accurate method of predicting pedestrian movement.

Vicinity, Decay and Gaussian Decay

One criticism that could be made of the new angular representation was that the methods of relativisation introduced above (Equations 4.1, 4.2, 4.3 and 4.4) assume a fixed unit interval between connections. Thus, the concept of radius 3 integration, which is vitally important to understanding pedestrian movement in a larger graph, was unavailable in the angular context. In his paper, Dalton (N.S. Dalton 2005) observed that the integration equations also implicitly assumed that there was a strong correlation between the number of items below a fixed radius and the total depth of those items, an assertion that could not be made for angular depth.

Creating an equivalent equation for normalising angular depths would be difficult and a subject of high level research in its own right. Dalton (N.S. Dalton 2005) suggested that an alternative mechanism might be used as a temporary proxy. In the global case, it is unnecessary to relativise the integration values, since the total depths are comparable to the number of nodes encountered across a single system. Dalton's proposal was that fixing the number of nodes rather than the steps away would make it possible to compare the total depths directly. The Set L of vicinity v can be defined as:

$$V_\upsilon = (\exists \in G \ni \left[\left(\sum_{n=1}^{n=V} L_v \div \right) \right]$$

Equation 4.6

Axial map	Vicinity V~ R3	R2 Correlation
Barnsbury 4	25	0.936
Shiraz Modern	17 (1/v)	0.849
Amsterdam	22 (1/v)	0.9158
London	25 (1/v)	0.90184
Nottingham 94	14 (1/v)	0.9025
Barcelona (1997)	45 (1/v)	0.8857
Warsaw	27 (1/v)	0.90696
St Louis (-HW) 12/02/2000	27 (1/v)	0.89885
New York Ped	91 (1/v)	0.9034
Atlanta 13/1/1995	26 (1/v)	0.89321

Table 4.2 Correlation between radius 3 and reciprocal of total vicinity for a number of cities, with the best depth shown.

Or, the vicinity subset of G (Vv) is a subset of G (the system) of size v, which has the smallest sum (total depth).

For example, consider node J, where the gamma map or J-graph of the steps has been computed for this node. These depths could be considered as an ordered set of rational numbers (sorted) V. In a hypothetical case, consider two sets V1 and V2:

V1 = (0 , 1,1,1,1,1,2,2,2,2,2,2,2,2,2,2,3,3,3,3,3,3,3,3,3,3,3,3,3,3,4,4,4,4,4,4,4,4,5,5,5,5,5,5)

V2 = (0,1,1,1,1,1,1,1,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,3,3,3,3,3,3,3,3,3,4,555555555555)

In the case of radius 3, we begin measuring the structure of the local neighbourhood by creating subsets V1R and V2R, which in the case of radius 3 would be all of the items with 3 steps. If this was a social network, these would be all of the people who were friends of friends of friends, excluding any duplicates. For the sets above, these subsets would be:

V1R = (0 , 1,1,1,1,1,2,2,2,2,2,2,2,2,2,2,3,3,3,3,3,3,3,3,3,3,3,3,3,3)

Figure 4.18(a): Barnsbury radius 3 integration.

Figure 4.18(b): Barnsbury log of vicinity 30 integration.

Figure 4.19: Barnsbury decay integration d=4.

V2R = (0,1,1,1,1,1,1,1,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,3,3,3,3,3,3,3,3,3)

In this case, the total depth (total status) will be 65 for V1R and 74 for V2R; so V2R has a larger cumulative depth than VR1. In the radius case, we have to also be aware that the number of items in each set is different, 30 in the case of V1R and 37 in the case of V2, and somehow make allowance for this[3].

For vicinity, the size of the subset is fixed to the vicinity parameter, so the vicinity 10 subset would be:

V1V = (0,1,1,1,1,1,2,2,2,2,2,2,2,2,2,2,3,3,3,3,3,3)

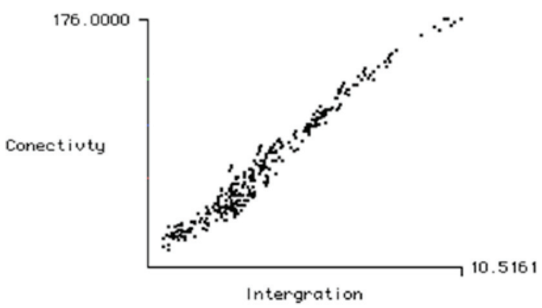
V2V = (0,1,1,1,1,1,1,1,2,2,2,2,2,2,2,2,2,2,2,2,2,2)

This gives an accumulative depth of 43 and 35, respectively (see Fig. 4.18 for a comparison of radius and vicinity maps). This method has been accused of being arbitrary, that is, node 10 of depth 2 is included in the set but node 11 of depth 2 is excluded. In the case of step depths, it is argued that this arbitrariness is irrelevant. While node 10 might be an insignificant back street and 11 an important high street, their contributions to the cumulative depth are identical. That is, if we swapped node 10 for node 11, the former node 11 would still contribute 2 to the cumulative depth, thus not affecting the sum in any way. When considering the step depths, the 'arbitrary' decision to include one node and exclude another is irrelevant, since the sums are identical in each case. Thus, while all of the nodes that are two steps away from the origin are different, their contributions to the cumulative depth are identical and interchangeable, and so not 'arbitrary'. When considering angles and fractions, the ordering of values will be less arbitrary, thus eliminating the objection. Ultimately, it can be seen in the case of vicinity that having a fixed set size makes the two systems directly comparable - dividing by the size of the set is irrelevant as the division is by a constant. Fig. 4.18 shows two axial maps coloured by radius 3 integration and vicinity 30, demonstrating the apparent similarity between the two measures. Table 4.2 shows the optimal correction for a number of different cities, showing that the value of the reciprocal of vicinity correlates strongly with radius 3 integration, but does so at a number of vicinity values.

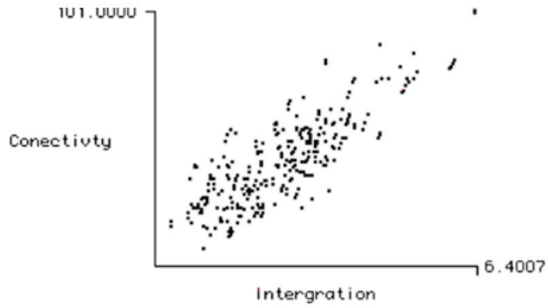
As an alternative, Dalton and Dalton (N. Dalton and R. Dalton 2007) also suggested the use of depth decay as another way of introducing a relativisation process into angular or weighted systems. With the radius process, only the items within N steps of the starting point are used. This creates a situation where the total depths, given a number of different nodes, are compared, a problem handled by the RRA and D-value equations. The decay solution to this is to include all of the elements in the system. In this case, for a single system, the number of elements is a constant and so, as in the unlimited or global radius version, has no effect. To create a lens that prioritises the local over the global, the decay mechanism raises the depth to the reciprocal of the square of the depth or d to the power of –2, and in the general case experiments with d to the power of –d, where d is a value analogous to 'radius'. With decay, the further out elements contribute to the overall total depth, but do so with some vanishingly

3 Even though, as Dalton showed, there is generally a very high (>0.99) correlation between cumulative depth and number of items in most radius based cases.

Figure 4.20: Barnsbury Gauss integration g=2.



High intelligibility scattergram



Low intelligibility; source Space is the Machine

Figure 4.21 (a) high (b) low intelligibility scattergram; source (Hillier 1996).

small incremental contribution. This prioritising of the local over the global creates a radius-like effect (see Fig. 4.19). Decay is defined as

$$D_{N,s} = \sum_{k=1}^{k} \frac{1}{d(n_k)^s}$$

Equation 4.7

where the decay integration factor for a node N is the sum of the reciprocals of all of the node depths d(n) of node n to N raised to the power of s.

Another way of computing this kind of decay is to compute the sum of e raised to a negative power d squared divided by a constant g (see Equation 4.8). Again, as can be seen in Fig. 4.20 above, this produces an axial map that looks very similar to that of radius 3 but has slight variations.

$$G_{N,g} = \sum_{k=1}^{k} e^{d(n_k)^2/g}$$

Equation 4.8

As of this writing, no consensus had been reached in the community as to how to handle radius measures in a general way in a segmental system. More complications have arisen, with Hillier introducing the use of a metric radius along a segment as a powerful way of measuring local grid intensification, which bears witness to the signature of local shopping streets. While fascinating, this segmental

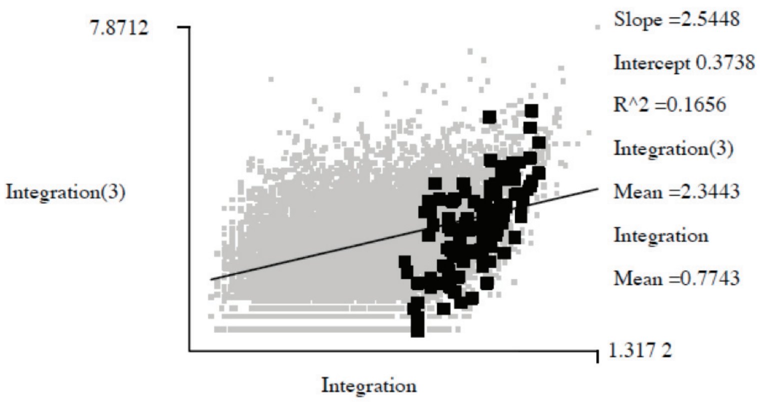


Figure 4.22 An example of synergy for a local area (black dots) against that of the city (grey dots); source: Space is the Machine.

mechanism lacks generality and makes a comparison between the axial and segmental radius mechanisms practically impossible.

Intelligibility

In Space is the Machine (Hillier 1996), Hillier also introduced an important concept that will be of use in this thesis, that of intelligibility. When considering an urban axial map, the inhabitant of an urban environment can only perceive a small portion of the entire system. This perception implies that the inhabitant can only see the local values for an axial line, most notably connectivity (degree in graph theory terms), the number of connections one space has to another. Hillier observed that for navigable areas, there was a high correlation between connectivity and global integration. This property, which he labelled intelligibility, was defined by Hillier as follows:

> *'The property of 'intelligibility' in a deformed grid means the degree to which what we can see from the spaces that make up the system - that is, how many other spaces are connected to it - is a good guide to what we cannot see, that is, the integration of each space into the system as a whole. An intelligible system is one in which well-connected spaces also tend to be well-integrated spaces. An unintelligible system is one where well-connected spaces are not well integrated, so that what we can see of their connections misleads us about the status of that space in the system as a whole. We can read the degree of intelligibility by looking at the shape of the scatter. If the points (representing the spaces) form a straight line rising at 45 per cent [degrees] from bottom left to top right, then it would mean that every time a space was a little more connected, then it would also become a little more integrated - that is to say, there would be a perfect "correlation" between what you can see and what you can't see. The system would then be perfectly intelligible. In Fig. 3.14e, the points do not form a perfect line, but they do form a tight scatter around the "regression line", which is evidence of a strong degree of correlation, and therefore good intelligibility. In Fig. 3.14f we find that the points have become diffused well away from any line, and no longer form a tight fit about the "regression line". This means that connectivity is no longer a good guide to integration and therefore as we move around the system we will get very poor information about the layout as a whole from what we see locally. This agrees remarkably well with our intuition of what it would be like to move around this "labyrinthian" layout.' (Hillier 1996, 94)*

One property that Hillier observed in areas of what he describes as 'disurbanism' (for example sink housing estates) is that the degree of correlation breaks down, making the layout less understandable (see Fig. 4.21). That is, designed but less well functioning areas exhibit complex spatial properties that can be detected using the intelligibility measure, as an example.

Synergy

Similarly, in Space is the Machine (Hillier 1996), Hillier also made an interesting observation about looking at the correlation between global (radius n) integration and local integration radius 3 (see Fig. 4.22 as an example).

> *'Research has shown that the critical thing about urban sub-areas is how their internal structures relate to the larger-scale system in which they are embedded. The best way to bring this out is to analyse the system for its integration at two levels. First we do ordinary integration, which counts how deep or shallow each line in is from every other line. Second we count how deep or shallow each line in is from all lines up to three steps away. The latter we call radius-3 integration, since it looks at each line up to a radius of 3. The former we can call radius-n integration. Radius-3 integration presents a localised picture of integration, and we can therefore think of it also as local integration, while radius-n integration presents a picture of integration at the largest scale, and we can therefore call it global integration.'(Hillier 1996, 99–100).*

Note: The term synergy for this was introduced in a later publication (Hillier 2001).

As mentioned previously on the subject of localisation, radius 3 integration differs from but generally correlates with global integration. One observation made by Hillier is that for a classically structured area of a European city, 'there is generally a reasonable correlation between global integration and local (radius 3) integration.' This means that there is a 'good interface' between global and local movement, that is, a busy local street will also be a busy global street or as Hillier puts it,

> *'The linearity implies a good relation between local and global integration, the steeper slope across the regression line implies that the most integrated lines within the city, which are the lines from the outside towards the centre, are more locally than globally integrated. Their local integration is, as it were, intensified for their degree of global integration. Repeating this experiment with all of the well-known named London areas, such as Soho, Covent Garden, Bloomsbury, and even Barnsbury yields this kind of scatter. In other words, the relation of part and whole in the axial map is made up at least in part of the relation between local and global integration. The reason this is so is that each local area has its heart linked to the supergrid lines that surround it by strong integrators. These form an edge-to-centre structure in all directions, and the less-integrated areas are within the interstices formed by the structure. The strong local integrators which define the slope of the dark points for the local area are invariably these edge-to-centre lines' (Hillier 1996, 128-129)*

Further, Hillier observed that this property, later labelled synergy (relating the co-evolution and co-function of the local and global movement economies), was present in named subareas but not necessarily in randomly selected regions. This strongly suggests that synergy is related to the structure of a named area, as was pointed out in the problem definition chapter. It is this theoretical linkage between a named area and the local and global structures of space that was the strong theoretical indicator for this thesis. It should also be observed that the nature of synergy is based up some degree of local variation (or heterogeneity). A region which has no variation in global or local integration would have no measurable degree of synergy. Mathematically if this occurred then all the axial lines making up a sub area would occupy the same point on the scattergram leading with no the slope (technically the cross product would involve infinity). From this it can be seen that local heterogeneity is an inherent property of synergy.

Synergy and Segmental approaches

In the section on segmental approaches to integration, it was observed that at the time of writing there was no consensus on the relativisation of segmental maps in any general way. One of the important consequences of this is that there is no commonly agreed upon replacement for radius in a segmental map (although many proposals have been made). In the section on synergy, it was observed that radius is a fundamental component of synergy. Thus, the observations made by Hillier on the utility of synergy are in turn dependant on radius and as such on current axial methods. While synergy could be redefined in a segmental context, validating that would be a thesis topic in its own right. For this reason, this thesis was developed based on the theory arising from an axial approach to urban movement. While this approach is not incompatible with a segmental representation, the theoretical approach is highly rooted in axial mapping and this thesis will be limited to applying synergy in that context. It was felt, as the basis for this approach, that moving to segmental representations, while interesting, would stretch the practical and theoretical basis beyond a reasonable degree while still maintaining a link back to the theoretical basis of intelligibility and synergy.

Key points

- This chapter was an introduction to space syntax.
- The spatial basis of space syntax is the quantisation of space into:
  - convex spaces
  - isovist spaces
  - axial spaces
- The basis for integration was introduced as a topological measure of the structure of the intersection of spaces.
- A correlation with observed movement patterns was made.
- The use of radius to provide a local pedestrian view was discussed.
- The measure choice was introduced and discussed.
- Angular measures were introduced as a refinement of the topological methods.
- Methods such as vicinity, decay and Gaussian extension were introduced as alternatives to radius in an angular context.
- Segmental methods were introduced as a refinement of the axial measure.
- The basis of intelligibility and synergy as area methods was presented.
- The basis for intelligibility and synergy is rooted in the axial map and the applicability of these methods to segmental maps is highly uncertain; hence segmental models are not used in this thesis.

Chapter 5: The Theory of Local Continuity in the Spatial Visual Field (Revelation)

Summary

This chapter begins with the second part of the place hypothesis, that the character of a place is informed by the local variations in a given continuous region. It is asserted that it is this distinctiveness that makes one place different from another and the unique notion is suggested that this distinctiveness can be expressed partly through the medium of space. The chapter goes on to review the work of the environmental psychologists Kaplan and Kaplan, who introduced a number of techniques to measure the emotional response to locations. This work, which has been frequently repeated in the field of environmental psychology, provides a large body of evidence to suggest that people respond emotionally to aspects of their environment, thus supporting the place hypothesis. One of the distinctions of Kaplan and Kaplan is the separation of images into those that suggest coherence, complexity, legibility and mystery. These visual divisions are reminiscent of the work of Benedikt, who introduced the notion of the spatial isovist. This chapter returns to the work of Franz and Weiner, who introduced the concept of revelation as the change in area in the isovist area from a point. The chapter continues with work on revelation and suggests how it relates to the environmental concept of mystery. Moreover, it shows how revelation (or new space, to use Benedikt's term) can be measured. The chapter goes on to introduce new software and visualisations of the revelation field based on the isovist grid and, from these, suggests that revelation may benefit from a slight mathematical reformulation. The chapter goes on to introduce a new visualisation of the revelation field and shows how axial revelation can be computed and used as a low resolution revision of isovist revelation.

In the problem definition, the place hypothesis was stated as follows: 'place is an expression of global continuity and the unique identity of space while at the same time being matched by an absence of local continuity in the spatial visual field as measured by revelation'. The concept of a neighbourhood place as a continuity of character is hardly a new one, being explored by both Lynch (Lynch 1960) and Norberg Schulz (Norberg-Schulz 1976), among others. Local continuity was intuitively not adequate for a complete definition of place. For example, the Sahara desert is of a largely continuous character (Sand, Sky, Dunes), but while this is a region (a large scale place), one might not think of it as a place like Islington. More tractably, a large housing estate with an ample supply of buildings does not appear to have the same rank as a village in terms of being a place, despite the likelihood that they are on the same order in terms of the number of buildings.

The second part of the place hypothesis is the element that the local differentiation of space is high enough to form identifiable distinctiveness, both giving a traveller the ability to locate themselves uniquely and providing a non-monotonous environment through which to move. It should be stated that the space experienced should not contradict the larger scale regularities of the first part of the hypothesis. For example, on a university campus such as Warwick University of Sussex university, the near randomness of location of buildings produces local uniqueness, but it lacks an overall clarity of spatial structure (it is unintelligible).

The notion of local variation as a basis for the emotional effect of environment has been the subject of extensive research by environmental psychologists, such as Kaplan & Kaplan (S. Kaplan and R. Kaplan 1982). Environmental psychology has a long history of measuring the environmental properties that can be attached to emotional states; for example (S. Kaplan 1988) (Stamps 2000) (Stamps 2004).

As Franz and Wiener (Franz and Wiener 2005), suggest the link between environmental conditions and physiological states can be easily established; think, for example, of claustrophobia or agoraphobia, a fear of one or another kind of space. On a less dysfunctional level, we might think about our response to descriptive terms like 'spaciousness' and 'crowded' to see that we all share some kind of emotional response to space at various levels. Rachel and Stephen Kaplan went deeper by postulating that people have the basic needs to understand and explore environments. Further, these needs apply to both that which we can immediately perceive and those we might perceive if moved to another location. Thus, a matrix of four states emerges: coherence (immediate understanding), complexity (immediate exploration), legibility (inferred understanding) and mystery (inferred exploration). They suggested that these four states are predictors of environmental preferences. It should be noted that they were approaching this from a general point of view and wished to apply this theory generally to both natural and built environments. Stamps (Stamps 2004) (Stamps 2004) reported that a large body of research has been developed over the last 30 years with over 61 papers reporting experimental findings related to these predictors. Again, it should be noted that the primary experimental methodology in these studies has been presenting photographs to a sample of individuals or experts and asking them to rate the pictures on a responsive scale of some kind.

The notion of coherence, complexity, legibility and mystery sit most naturally with the research presented so far, but with a single change of dimension. Legibility sits naturally with intelligibility or synergy as a measure of how well knowledge of the current state of the world can be applied to predicting the world beyond the currently visible. Mystery might be equally said to sit naturally with unintelligibility the lack of legibility requiring more exploration to attain it. Yet, we must also be aware of the differences. Environmental psychologists could be said to largely view the world from the perceptual point of view, that of

	Immediate	Inferred
Understood	Coherence	Legibility
Exploration	Complexity	Mystery

Table 5.1 Kaplan and Kaplan, emotional states of scenes.

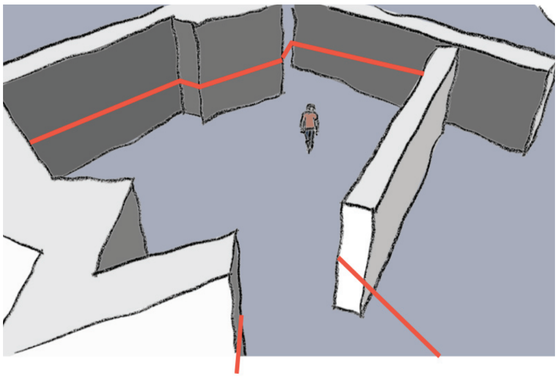


Figure 5.1 View of isovist (red line) from eye point of inhabitant.

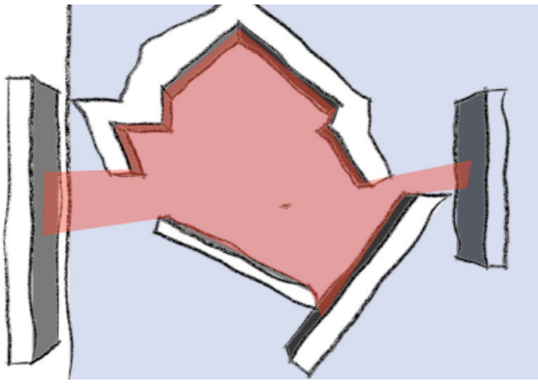


Figure 5.2 Plan view of isovist (red region) from eye point.

the image of the world that we see, compared to the largely objective, external and spatial mechanisms used to define the syntactic measures of synergy and intelligibility.

Given the linkage then, it is fruitful to look at the Kaplan states through the lens of space. If legibility corresponds to intelligibility or synergy, then it seems natural to attempt to determine the spatial analogies of coherence and complexity. From this point of view, it is natural to consider one of the more immediate measures of space, such as Michael Benedikt's Isovist (M.L. Benedikt 1979). The term isovist precedes Benedikt's use of the term. The term isovist was first used by Tandy (Tandy 1967) or, according to Montello (Montello 2007), was first used by Hardy (Hardy 1967). As mentioned in the Literature Review, Benedikt appears to be the first to apply it in the context of a building rather than landscape, as in Tandy's case.

An isovist is the planar polygon used in a plan to describe the limit of the viewshed or field of view for a single static viewer (Fig. 5.1 and Fig. 5.2). If one imagines a ray projected the eye, then the point of first intersection with the first occluding object defines a point in space around the observer. If the observer slowly rotates, the subsequent points would describe a path that is the isovist. As Franz and Wiener (Franz and Wiener 2005) pointed out, many of the basic properties of space, such as spaciousness, become directly measurable in relation to the area of the polygon. There are variations of Benedikt's isovist; we might, as Hardy did, consider the isovist as a full three dimensional volume (or more typically a hemispherical volume). We might also reduce the angle of the view, as Conroy (Conroy 2001) did. In this, the view around the viewing point is restricted; for example, we might consider the field of view of the average adult fixated on some point in space. From this we can consider a field of view of 112 degrees (56 degrees on either side of the axis of gaze), which is less than the full 360 degrees that Benedikt isovists would possess.

Before exploring more of the properties of the isovist, it is necessary to pause to consider what the isovist is measuring. For a full isovist, we are measuring an objective property of space. However, if we follow Conroy's concept of the restricted isovist, we are moving from an objective view of the build environment to an objective measure of an occupant's view of the environment, a point which, while subtle, has a profound effect on how the isovist should be interpreted as an object. Yet, as Conroy-Dalton points out, all of Benedikt's measures are implicitly embodied measures, as they are attempts to create measures of absolute space as it might relate to the body. For example, circularity and the area/perimeter ratio are attempts to measure the shape of a space and factor out the overall size. For instance, a square isovist 10 meters by 10 meters has the same area/perimeter ratio as one 1 m by 1 m. However, clearly the absence of scale implies that we could not consider this measure when thinking about the impact of space on a claustrophobic. Area, on the other hand, is an absolute measure, and so could be related to the body dimensions of space.

The polygon of the isovist has a number of properties that may be related to the experiential properties of the isovist. For example, the concept of spaciousness can be related to the area of the isovist, with a large isovist being spacious and a small one being 'confined'. Benedikt proposed a number of measures for the isovist that might be related to how one might view the space from that point, including area, perimeter, circularity (Equation 5.3), the number of vertices and the ratio of closed edges to open edges, with a closed edge being a side that lies on the face of an occluding surface and an open edge being one passing through an open space to a new occluding face. A high level of open edges to closed suggests that moving a little will reveal far more new information than would be the case if the ratio were low. Thus, we can think of this as a measure that is parallel to Kaplan's 'complexity' measure.

$$Perimeter = \sum_{n=1}^{n=m} \sqrt{(p_n^x - p_{n-1}^x)^2 + (p_n^y - p_{n-1}^y)^2}$$

Equation 5.1

$$Apr = \left(\frac{A}{p^2}\right)$$

Equation 5.2

$$Circularity = \frac{\left(\pi \left| r^r \right|\right)}{A}$$

Equation 5.3

Omnivista

Subsequent work on isovists by Conroy and Dalton (Conroy 2001) introduced a number of new measures describing the shape of space. These new measures included area/perimeter ratio ARP (Equation 5.2), dispersion (Equation 5.6), drift (Equation 5.5), maximum radial length (Equation 5.7), average radial length (Equation 5.4), and minimum radial length (Equation 5.8). Where A is the polygon area, p

$$averageradial = \bar{r} = \left(\frac{1}{m}\right)\sum_{\phi=0}^{\phi=m} r_\phi$$

Equation 5.4

$$Drift = \sqrt{(d_y - c_y)^2 + (d_x - c_x)^2}$$

Equation 5.5

$$Dispersion = (\bar{r} - \Phi)$$

Equation 5.6

$$MaxiumRadial = \left\lceil r_\phi \right\rceil_{\phi=0}^{\phi=m}$$

Equation 5.7

$$MinimalRadial = \left\lfloor r_\phi \right\rfloor_{\phi=0}^{\phi=m}$$

Equation 5.8

is the length of the perimeter (Equation 5.1), d is the location of the centre of gravity of a polygon, c is the ordinates of the point of view generating the isovist, $r_ø$ is the radius of the polygon at angle ø, and r(bar) is the average radial.

These reflected a new approach (at the time) to measuring the vista via a number of radials. These new measures were mixtures of abstract shape (area perimeter ratio) and absolute space, such as the minimum, maximum, mean, variance and skewness of radial lengths. These measures began to attempt to measure the symmetry of a space, leading to the measure of drift.

Drift is a measure of the difference between the centre of the generated isovist and the centre of gravity of the shape. Thus, if one is standing at a highly asymmetrical point in space, one is also standing at a point of high drift. While drift is fundamentally a vector quantity, it can be compressed into the length of the vector. Thus, higher values of drift indicate stronger asymmetries in the locus of the isovist.

$$U_{pq} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} (x-\bar{x})^p (y-\bar{y})^q f(x,y)\,dxdy$$

Equation 5.9

$$\text{where} \quad \bar{x} = \frac{M_{10}}{M_{00}} \quad \text{and} \quad \bar{y} = \frac{M_{01}}{M_{00}}$$

Equation 5.10

$$u_{pq} = \sum_x \sum_y (x-\bar{x})^p (y-\bar{y})^q f(x,y)$$

Equation 5.11

Image or Hu Moments

In the field of image recognition, a number of measures for the shapes of objects have been developed that describe shape in a way that is invariant to size, translation and orientation. While these techniques were initially developed by Hu (Hu 1962) for use in collecting pixelated image data, they are general and can be used on the hull (or polygon) of a shape. Here x represents the horizontal co-ordinate and y the vertical co-ordinator. Generally Image moments are computed as the deviation of the x co-ordinate from the mean raised to some power p and similarly the deviation of the y co-ordinate from the mean y value for a shaper raised to some power q. Thus a Moment M_{pq} represents the sum of all co-ordinates with power factors p and q. So M_{22} represents each co-ordinate deviation squared. These moments are used extensively and successfully in a number of fields, including the active field of robotics, to facilitate the recognition of space by the creation of aural and visual isovists. It would clearly be negligent, then, not to include these measures in the list of isovist measures that can be applied to an environment. Given the lack of any spatial theory behind them they should be seen as pure measures of shape being used as a comparative measure.

New space

It seems natural given the linkage between discovery and exploration that revelation be one of the factors we could expect to play a role in the local design of an environment. Benedict reinforced this notion by suggesting a number of enhancements to the concept of the isovist. One of the measures he proposes is 'new space', which begins with an isovist at a point in space x, considers all the surrounding isovists within some unit step distance (say 0.2m) and finds that space x' that has the most new space, that is the most space that is not directly visible from point x. You then move to that position and repeat with x' as x. This may create trajectories (paths of points) indicating the lines where the maximum new information will be gained (M. L. Benedikt 2000). Clearly, there are going to be points in space that create local points of stability or strange attractors. For example, consider two cells joined by a single doorway. In the first cell A, we might expect moving to B would give more 'new space' and that once in B moving back to A would again give more 'new space', thus causing an infinite oscillation between locations. Clearly no animal would consider a return to a previous location as 'new space'. Likewise, our deterministic algorithm might include the ability to remember previous isovists as 'old space'. Benedikt also fails to mention how the algorithm might end, perhaps with a point where only turning back would create new space, but this might terminate the algorithm at thresholds or doorways.

Benedikt's new space operates on a definition that is similar to the definition of revelation by Franz and Wiener and shares many of the same properties.

Franz & Wiener

Franz and Wiener (Franz and Wiener 2005) might be said to have objected to some of the previous work by stating that they considered that spatial measures should be born from an attempt to measure the property of space that relates to the impact of that space on the human cognitive function. They modified or developed new measures to match basic spatial qualities, including spaciousness, which is related to an isovist's area and free near (medium) space; openness, which is related to an isovist's openness, jaggedness and revelation; complexity, which is related to the number of vertices, along with the vertex density, jaggedness and clustering coefficient[1]; and finally, order, which is related to symmetry and redundancy (see Fig. 206 of (Franz and Wiener 2005)).

What made the Franz and Wiener work significant was their approach to testing to what degree people might actually perceive or locate a space that might be relevant. For example, when asked to find the best place to hide, the point chosen also correlated well with the point of smallest isovist area. Equally, the point with the best overview was strongly correlated with a point of largest isovist. Their studies showed that in the context of a gallery, a number of the measures correlated well with the locations assessed by their subjects.

Revelation Coefficient

Of the factors mentioned by Franz and Wiener, the concept of revelation, appears to be very applicable to the process of spatially assessing the local observable space that one might pass through in a place. The measure of revelation, like Benedikt's new space, is an attempt to

1 A clustering coefficient is a term rising from social graph theory. When you have a group of friends the likely hood that if A is friends with B and B is friends with C then A is friends with C. The clustering coefficient is a measure of how similar A's connections are to the connections of A and can range from 0.0 to 1.0. It has been found in many cases of small world graphs that high clustering coefficients are common. Unusually Axial map graphs and convex space graphs typically have very low clustering coefficients.

measure the degree to which new information is available in a space,

> *'a more behaviourally oriented measure was designed called revelation coefficient that was calculated on the visibility graph as the relative difference between the current and the adjacent isovist areas. Similar to the clustering coefficient, a high revelation coefficient indicates an area of low visual stability and potential information gain by moving further. Revelation might be especially relevant when actively navigating' (Franz and Wiener).*

The idea of visual stability is also an interesting way of treating our cognition of space, related to Kaplan's concept of 'mystery'. The revelation coefficient is calculated by looking at a grid of four or eight isovists neighbouring the starting isovist S when considering isovists calculated in a grid as found in VGA analysis (see below), and computing the differences in their extents (areas). The sum of all the differences is then normalised by the size of the starting isovist. Thus, the area of the isovist is eliminated, leaving only a factor; for example a value of 2 means that twice the current space is available.

$$\mathrm{Re}velation = \frac{1}{AreaS}\left(\sum AreaI - AreaS\right)$$

Equation 5.12

Generally in this thesis I will use the term revelation to refer to the general concept behind the revelation coefficient of Franz and Wiener and Benedikt's concept of new space, leaving the term revelation coefficient or f-revelation to denote specific definitions of the quantity of revelation as found in Equation 5.12 where AreaS is the area of the starting isovists and AreaI is the area of the I surrounding isovist.

T partitions and S partitions

The notion of revelation, or the attainment of new information, was also at the centre of the work of (Peponis 1997). Here, the basis was not that of a point in space, but the extension of occluding surfaces, such as walls, to identify the thresholds where new information might be encountered. From Peponis' work, we see that by extending the occluding surface until it forms an intersection with another surface, we create a surface partition (S-partition). If that S-partition crosses free or open space, then we can conclude that passing over S partitions will yield new information and, as such, be a moment of revelation. If we hold that a space is an area of constant information (when you are in a room you don't see more by moving), then we might assert that the S-partition is a method to create a partition for a space. Yet, this technique does not make it easy to quantify to what extent new information is encountered; it only makes it possible to measure to what extent or density a building or environment might create new information[2].

Isovist grids

No review on isovists would be complete without reference to the work of Turner and Penn (Mottram et al. 1999) (A. Turner and A. Penn 1999) (A. Turner et al. 2001) (A. Turner 2003) on isovist grids or visibility graph analysis. Prior to Turner and Penn, isovists tended to be used, either singly or comparatively, to

2. From a rendering point of view, the floor partitions created by S-partitions are zones of 'constant information'. If hardware rendering were now not so ubiquitous it would be possible to create an efficient algorithm where a game world was portioned using S-partitions and then the set of occluding surfaces was precomputed and attached to the S- partition. The rendering algorithm would then depend upon taking the predefined occlusion set and rendering those portions that are before the virtual camera.

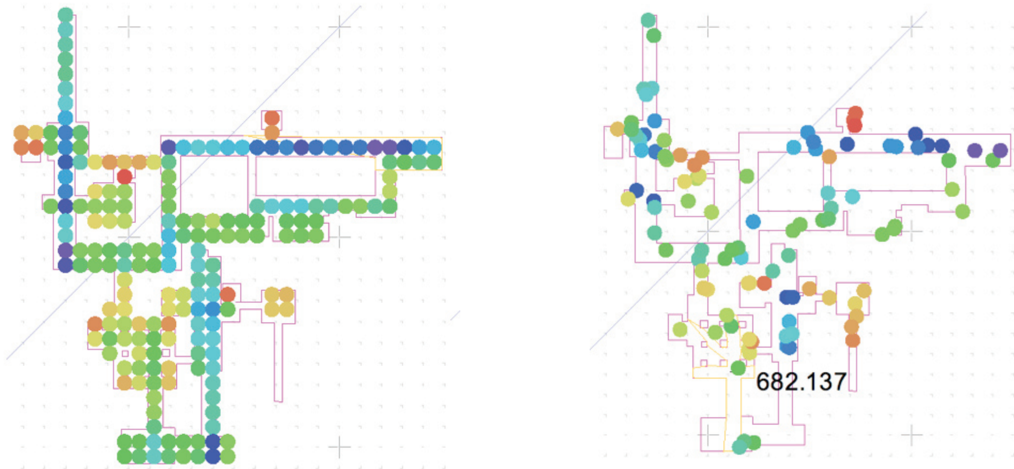


Figure 5.3 (a) An example of the spacing problem in a gridded isovist with (b) a stochastic isovist for comparison.

quantify aspects of space; for example Peatross (Peatross 2001) measured how space relates to criminal access.

An isovist grid is simply a visualisation of one of the many values visualised as a colour applied to a computed grid. A series of isovists are computed for a regular grid of loci and normalised values are applied as colour to circles at the loci points. The work of Turner and Penn moved the concept forward by attempting to merge traditional space syntax with the isovist by using the interpenetration or the centroid overlap to define the adjacency or non-adjacency of nodes. The graph can then be used to compute a standard syntactic measure, such as mean depth or integration. Turner and Penn showed evidence that suggested that such isovist integration maps can correlate well with moving pedestrian or visitor counts for a building space like a museum or a department store. This work generated a great deal of interest and has subsequently been refined by a number of papers, such as (A. Turner et al. 2001).

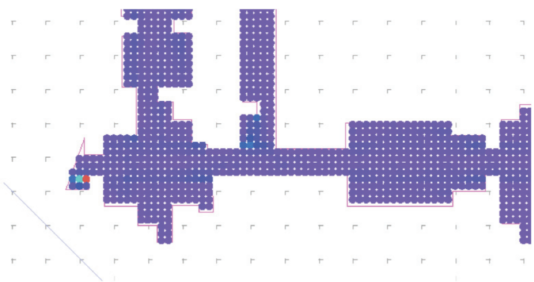


Figure 5.4 Franz & Wiener's Revelation in gridded configuration.

It should be noted that isovist maps break many of the common properties found in axial and convex space maps; for example axial maps and convex space maps tend to show very poor clustering coefficients, while isovist graphs show a more typical high clustering coefficient typical of small world networks. Thus, we must be careful when applying mathematics and other concepts developed for axial map graphs to isovist grid graphs and visa versa.

Random Isovist graphs

One of the motivations behind VGA grid or isovists was the sometimes erroneously asserted assumption that axial maps are not automatically reproducible. One of the problems with gridded isovists is the spacing and origin of the grid. As can be seen in Fig. 5.3, too low a resolution for the grid may lead to some areas not being recognised as part of the spatial continuity of the system. One operational solution to increase the resolution of the grid can lead to considerable increases in the rendering time required, but no published work has yet to show the sensitivity of the analysis to these broad operational adjustments. One alternative proposed in this thesis is the possibility of creating a stochastic grid isovist. In this case, points are randomly assigned within the boundaries of the building for analysis and then computed as normal. Fig. 5.3 shows a random isovist. It is suggested that one of the primary benefits of this mechanism is that it can also remove problems with non-orthogonal buildings, where spaces may run diagonally in strange orientations. One problem with this method is that the implementation of revelation becomes dependent upon finding those points in space that are near the source, since a node that is slightly beyond the limit of a 'step,' yet is fully visible, will not be included in the neighbourhood of the starting space.

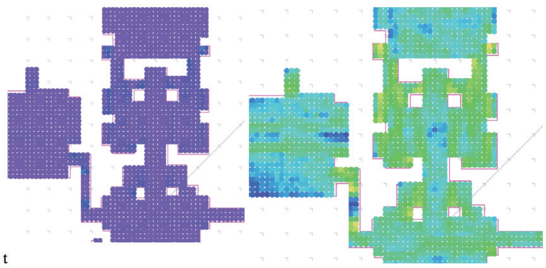


Figure 5.5 (a) f-revelation (b) Log(f-revelation)

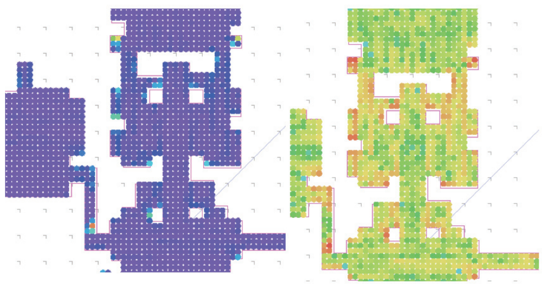


Figure 5.6 (a) s_Revelation (b) Log(s_Revelation)

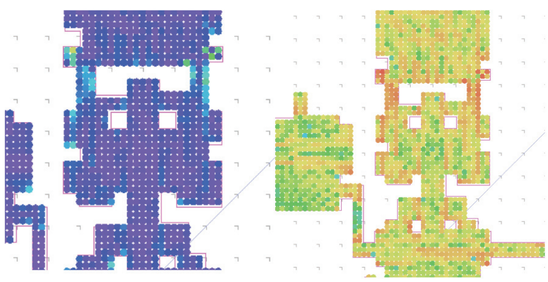


Figure 5.7 (a) b_revelation (b) Log(b_revelation)

Isovist paths and restricted isovist paths

In her PhD thesis, Conroy (Conroy 2001) introduced the concept of a path isovist, which is 'unfolded,' that is the value is plotted horizontally along the path in a chart, permitting the user to study the change in one or more variables along a path. Conroy's paths were collected by tracking participants in a virtual environment and, as such, could be extended slightly to introduce the concept of a restricted isovist path. In this restricted path, the field of view (of an adult or the restricted one of a head mounted display) was used to restrict the limits of the isovist. As mentioned, this is no longer strictly a measure of the building but becomes a measure of both the participant and the environment.

Proposed modifications to the revelation mechanism

One of the problems with revelation, as defined by Franz and Wiener, is that the degree of change is normalised for the original area but is not normalised for the number of adjacent isovists. For example, if we move away from a corner, we may be moving to a point with only three or possibly two adjacent cells, with considerable differences compared to a similar difference in a fully connected system.

Fig. 5.4 shows the result of computing and visualising the Franz and Wiener value for revelation, clearly demonstrating that a point of maximum revelation (value = 72.4) the high values generated by this revelation equation appear to mask out the more subtle points of revelation where one would expect them at the thresholds between spaces. To counter this, a new version of revelation was used. This has two formulations, one which is area insensitive and the other which is absolute area sensitive. The first version is formulated as Equation 5.12.

$$s\mathrm{Re}velation = \frac{1}{area_s n}\sum_{m=1}^{m=n}\left|area_n - area_s\right|$$

Equation 5.13

shows a formulation of s-revelation much like that of the revelation of Franz and Weiner (f-revelation for clarity), except the value of revelation is also divided by the number of nodes adjacent to the origin node s. As in revelation, s-revelation typically has up to eight adjacent neighbours. Fig. 5.6 shows a plot of the adjusted new revelation (s-revelation for clarity), which should be compared to Fig. 5.5. It should

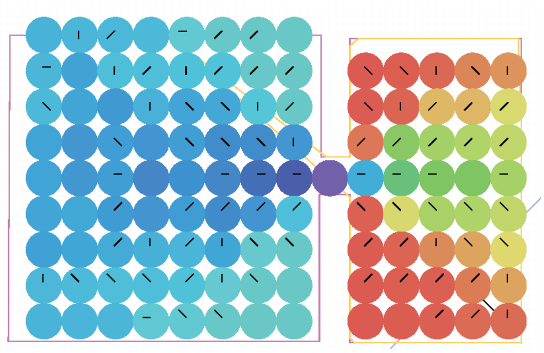


Figure 5.8 Plot of gridded isovist of area showing revelation gradient vectors.

also be noted that the differences are taken as absolute values, making the assessment that moving from a larger to a smaller space is the same as moving from smaller to the larger. The Franz and Wiener revelation value implicitly suggests that if one is on a route of steadily declining space (a corridor getting narrower and narrower) then the increase in space behind balances the decline in front, to match a corridor with no change in space, which is a concept that does not feel intuitively tenable. In all cases of revelation, the distribution of values is the log of revelation, giving a stronger degree of differentiation of values.

A second and more arguable case is that of normalising the change in value for area. For example, the Franz and Weiner revelation concept assumes that moving from a 1m wide space to a 2m wide one (say the difference between walking through a door and a double set of doors) is the same explicit experience as moving from a 10m wide imposing space to a 20m wide one. Recognising the value of the kinds of tentative embodiment that the value of isovist area and notions like free near (medium) space imply, it is potentially productive to include a version of revelation that does not normalise for area. This leads to body revelation (bRevelation), which can be defined in the formula below:

$$b\mathrm{Re}velation = \frac{1}{n}\sum_{m=1}^{m=n}\left|area_n - area_s\right|$$

Equation 5.14

Thus, the relation between sRevelation and bRevelation is

$$b\mathrm{Re}velation = area_s \times s\mathrm{Re}velation$$

It can be seen in Fig. 5.4 and Fig. 5.6 that the two versions are subtlely different in terms of what they treat as the most significant revelation space, compared to Fig. 5.7, the logarithm of b-revelation.

Revelation gradient

Strongly inspired by the concept of Michael Benedikt's new space paths, it would be tempting to automate the process and then attempt to produce the result of many paths together. One way to produce a visualisation of the all new space paths while avoiding some of the pitfalls already mentioned might be to return this new space or revelation measure back to a pure measure of the building, rather than a measure of space from the viewpoint of a particular observer. One way to do this is to plot a vector on the isovist point indicating the direction or gradient that would maximally increase the new space or revelation. Given that revelation is computed using an eight point compass around the loci or centre of the isovist, it makes sense to make the revelation gradient vector point in one of the same eight cardinal directions. In practice, there are nine directions; if a space is the largest isovist for its neighbourhood (with a 2% area fuzzy limit

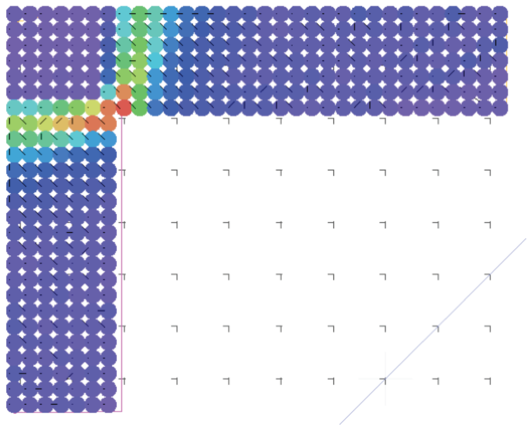


Figure 5.10 L shaped space with isovist gradient and coloured by revelation.

for numerical error) the vector points vertically down (and appears as a point or not at all).

Fig. 5.8 shows the revelation vectors plotted over the isovist areas. Notice that the area values are coloured with the smallest values in red and the largest isovist areas in blue. As we might expect, the largest isovist (violet) is at the centre of the doorway between two rooms/cells. Near the doorway, all of the revelation vectors point to the doorway. One oddity is that near the corners of the rooms, in many cases, the value appears to be unchanging. We might expect that if one is in a corner of a room and can see a doorway, one might expect to want to move to the doorway, but this is applying a cognitive model that is not incorporated in the revelation gradient construction. In many of the corners, moving slightly does not improve the isovist area encountered by a significant degree; there is no new space to encounter when the doorway is nearly edge-on. These gradient patterns make sense when considered in light of Peponis's S and T partition spaces (Peponis 1997). The corner spaces now point towards the near T partition lines.

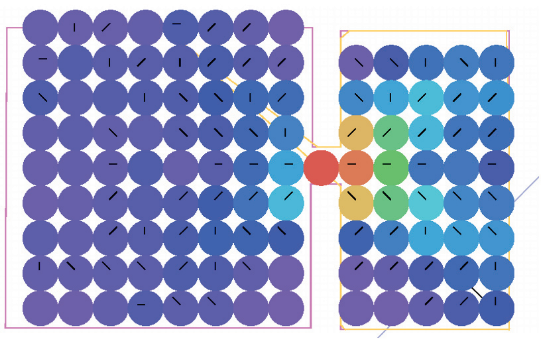


Figure 5.9 Plot of revelation for simple room system.

Equally, on the diagonal of the cell, we see a number of isovists pointing away from the doorway. This, again, is a collision between our semantic interpretation of the space as a room and the area computation of the model. Moving to cross the diagonal (crossing a T or S space) we are moving to a zone of more area and more potential information, as such moving away from the door is a good way to increase new space or revelation. It should also be noted that we are potentially suffering from a point in gradient method that uses a grid. In a grid, the isovist centres above, below and to the sides are unit (one) distance or a step away. Moving diagonally, we are moving $\sqrt{2}$ times further and so, in the right circumstances, are moving further and having the unfair advantage of potentially seeing more space. This, and the fact that the isovist is a numerical summation of the radials and so prone to small numerical errors, can produce spurious vectors.

Plotting the s type revelation computed in Interstice (Dalton), we see that Fig. 5.9 shows the values we might expect. Here the highest level of revelation is, as we would expect, at the doorway and leading up to it. It is interesting to observe that moving from a small space to a large one has a stronger gradient than moving from the larger space to the smaller – that is we see the orange and green points of revelation on one side but not on the other. This might be appreciated as a sign that moving from the smaller space to the larger is gaining considerably more space or new space than that gained from moving from the larger space to the smaller..

In Fig. 5.10 we can finally see how revelation and gradient change interact. The gradient change tends to point to the outside wall and then up to the top left hand corner. This is a natural point, since it permits an inhabitant of the space to survey the space in its entirety. On the other hand, the point of highest revelation indicates the point in space that permits the largest change. In a building setting, this would be the place to stand and 'peek' around the corner to see the next section.

We can conclude from these simple examples that s-revelation operates as we might expect but that space is more subtle than we might expect. It also reinforces the fact that we are dealing with objective measures of space rather than simplified cognitive models.

Axial Revelation

So far, revelation has been shown to be largely a product of a highly fine scale isovist representation. Yet, the concept of revelation is not limited to this representation. If we consider revelation as an attempt to measure a change in the perceptive environment, then nothing prevents this from being attempted in convex or axial representations.

For an axial representation, it is possible to consider the intersection of two axial lines. Normally, this would form an edge in the graph representation of an axial map. Yet, if we consider that an axial line describes a space, no matter how simply, then the intersection of two axial lines represents a transition between spaces. As such, we can consider the intersection of two axial lines as a point of transition or a point of revelation - a change in the information space. If we think of revelation as the change in area and we assume that the axial lines represent roughly equivalent width spaces, then a change in line length is a change

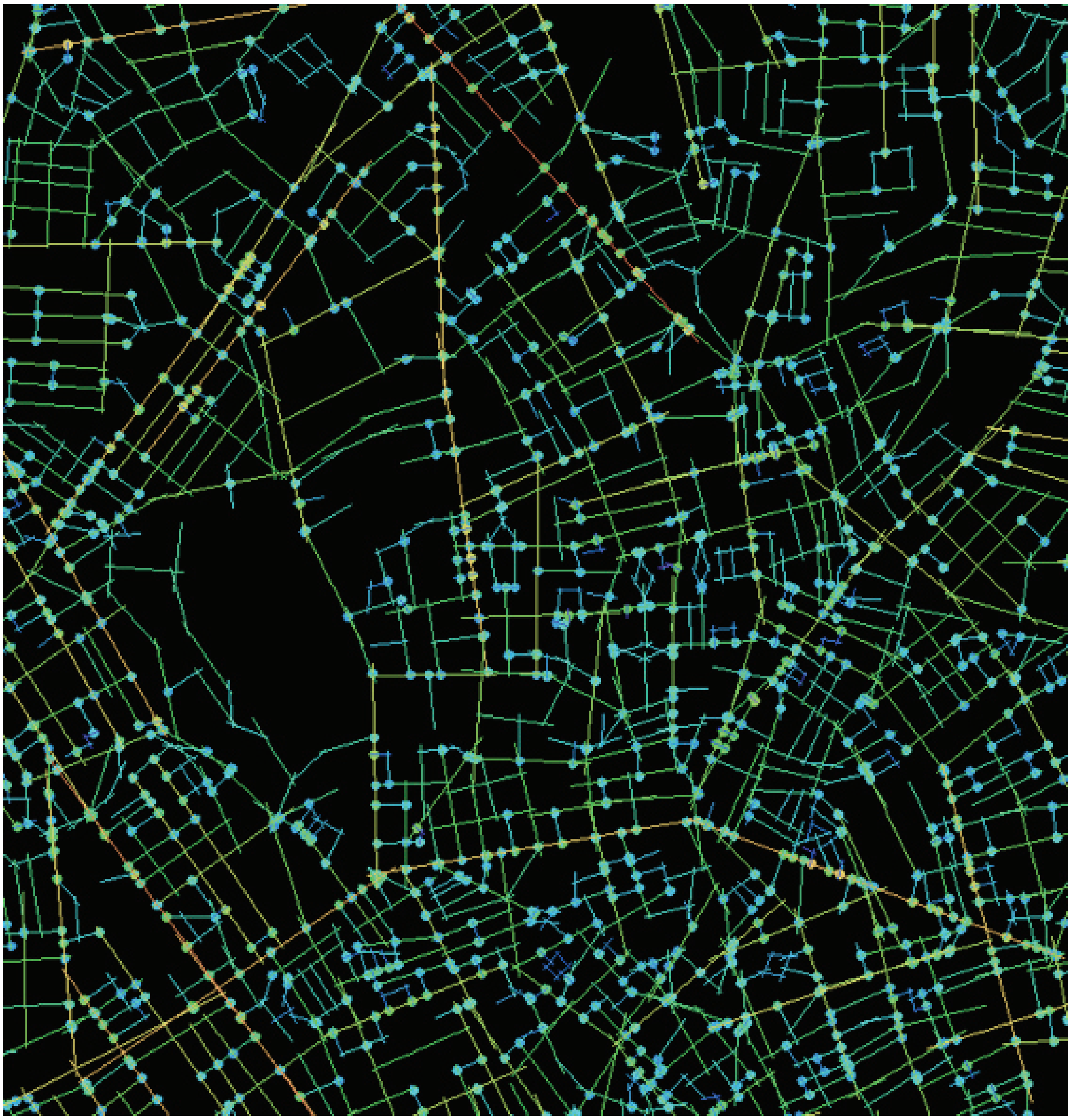


Figure 5.11 Plot of axial revelation values for Barnsbury, plotting line length differences. Axial lines plotted by logarithm of line length.

in visible area and is, as such, a measure of revelation.

Axial revelation can be computed in three ways. First, as a difference in line lengths, that is, the absolute change in line length value; second, as a ratio of line lengths and, third, as the difference in the connectivities. The difference in connectivities assumes that what makes our perception of a space relevant is not the length or area but the number of connections that the space has. However, this seems less like the revelation previously described. Also, it is known that in most urban contexts, the axial line length is proportional to connectivity, so the measure appears redundant. In response to this ans Jane Jacobs (1961) discusses a street which appears overly long without many connections feels different from the same street with far more connections. In axial revelation, the assumption is made of moving from small to big or big to small. For the purposes of comparison, it is necessary to introduce a convention that the larger of the two ratios (a/b, b/a) is the one being used to represent a change from the smaller space to the larger. For the case of the absolute change in line length, the absolute value (positive difference) is used for the same reason.

This can be plotted back on to the axial map by colouring points using a scale from highest (red) to lowest (blue). This mapping was introduced into the webmap@Home software under the Layers/edge values facility. To ease the visual burden, no node point was plotted if the difference was less than 10%, see Fig. 5.11.

Examining these values, we can see that evidently longer streets have more points of intersection. This is as would be expected, moving along a long axial line, we would expect that moving from a small space to a longer space would introduce more points of 'revelation'. We can also see that there are areas of small changes in revelation (no spots), such as behind Islington high street.

Relation between axial and isovist revelation

It is simple to explore the relationship between axial revelation and isovist revelation. If we begin with a simple block model for an area consisting of 48 identically sized blocks, all located within a larger holding zone, we can move the blocks around, leaving the area free for the isovists to be identical. While the nature of the gridded isovist process might create slightly more or fewer blocks, it is possible to divide the total reveal by the number of nodes/isovists to come up with a comparable

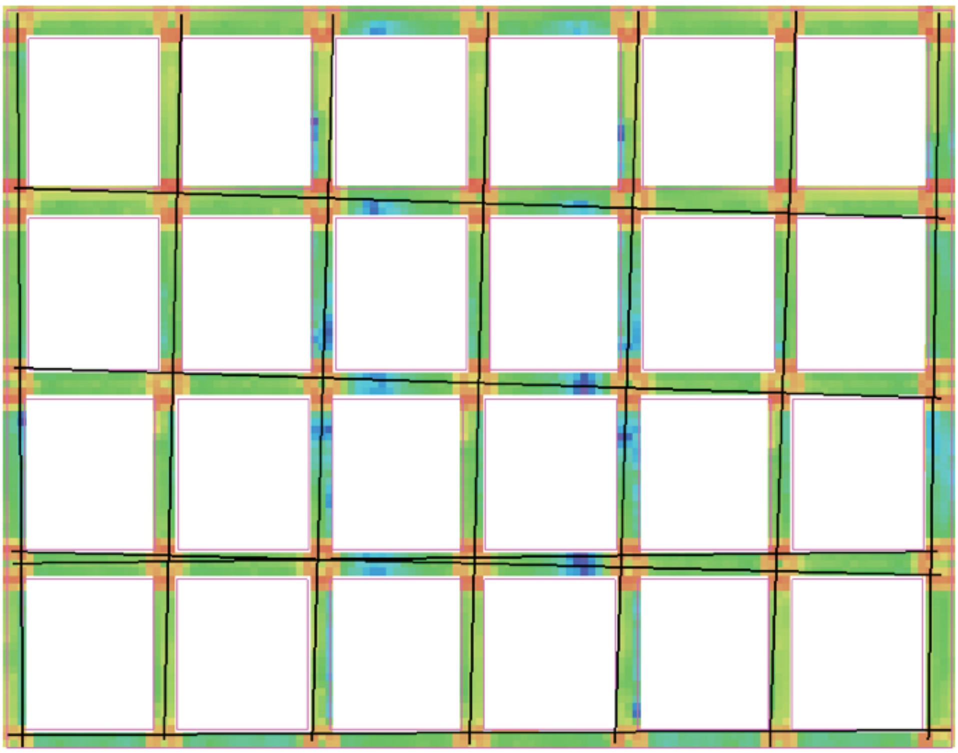


Figure 5.12 Test world 1, map of logarithm of S revelation.

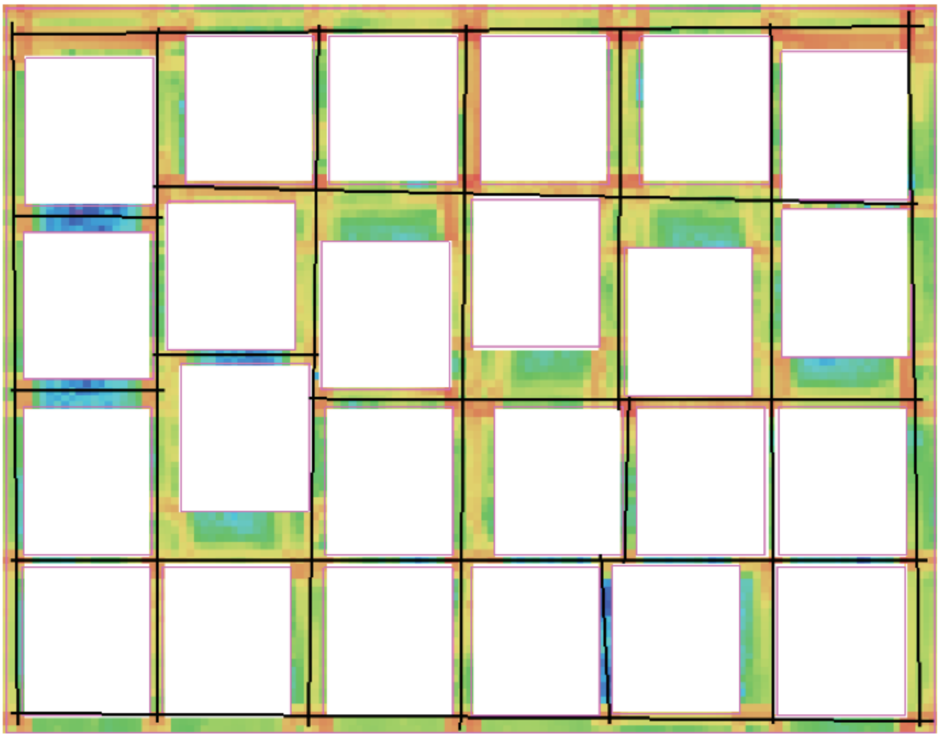


Figure 5.13 Test world 3, map of logarithm of S revelation.

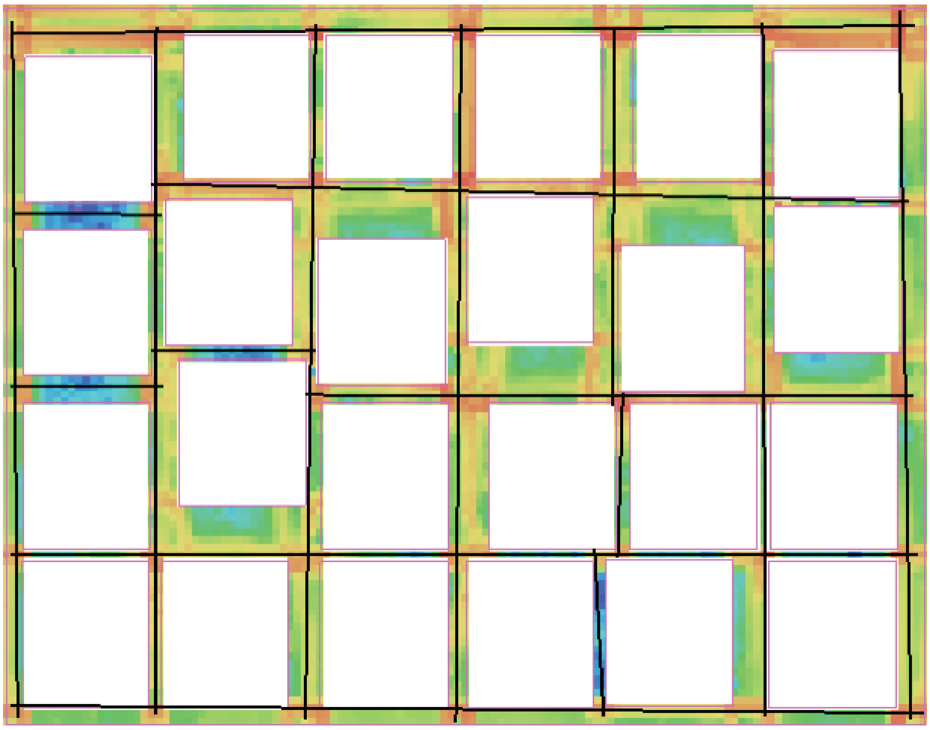


Figure 5.14 Test world 4, map of logarithm of S revelation.

map	Isovist revelation	axial revelation
revelation 1	4.59522405	1.7086753
revelation 2	4.46753772	1.5065941
revelation 3	4.37569804	1.1473499
revelation 4	4.42195743	1.5492503
revelation 5	4.20265807	1.03678122
revelation 6	4.12321046	0.49211614

Table 5.2 Values for cumulative s-revelation along with corresponding cumulative axial revelation.

number. If the isovist grid is used to compute s-revelation, we can produce maps of revelation, such as that below (given the range that revelation produces, it has been found useful to visualise the logarithm of s-revelation).

Along with the gridded isovist revelation, it is also possible to produce a corresponding axial map (black in Fig. 5.12, 5.13 and 5.14). While for the visitor to a space, the variation along a route would be the aspect of value, we can sum the total revelation for an entire map. By dividing this total revelation by the number of nodes (to allow for variation), it is possible to produce a number that can be thought of as a measure of the complete revelation for an area. It is possible to repeat this revelation process for axial maps representing axial length revelation. By creating a number of maps, from the highly ordered to the less formally structured, it is possible to create a range of artificial environments with which to test the space. Repeating this for a number of different arrangements, it is possible to produce the table above.

Table 5.2 shows the isovist revelation and axial revelation for a number of different block environments. Clearly, it is possible to create block designs that create a change in the gridded isovist revelation and yet have identical maps. We can, for example, think of a pure block cityscape, such as Manhattan, against the differentiated grid of Savannah. Yet, are small scale differences large enough to overwhelm the revelation detected at the axial level? Plotting the table above as a scattergram, where each point represents the total axial and gridded isovist relation for a single map, allows us to see that the points form a fairly tight group around a regression line. For the six block maps presented, we find a general r squared correlation of 0.885. This suggests that it is possible to broadly substitute axial revelation for local revelation when looking at a larger area rather than a smaller one.

Summary

This chapter began with the second half of the place hypothesis, stating that what was required was a measure of the local differences that might make a space rewarding to traverse, or that following the consistency of the large scale global spatial continuity might not be an ideal formulation for a place. Beginning with the work in environmental psychology of Kaplan and Kaplan (Kaplan and Kaplan 1982), we found a number of strong analogies to the kinds of local diversity that would be a good basis for the second part of the place hypothesis. Kaplan's concepts of coherence, complexity, legibility and mystery had some analogy with the spatial definitions of intelligibility. Environmental psychology typically stresses the visual contribution of our environment to our emotional state, making a good basis for topophilia, the linkage between environment and personal response, which is at the heart of place.

The core of this thesis is that place can be found, at least partially, in space (in the architectural sense of space) and, as such, it appeared logical to try to reproduce the work of Kaplan in a spatial rather than a visual context. To this end, the concept of an isovist, a local measure of space popularised in architecture by Benedikt, was introduced as the spatial mirror of the purely visual context of environmental psychology. A number of spatial measures that developed Benedikt's first work were introduced, as were the technique of the isovist grid and visibility graph analysis. The concept of revelation introduced by Franz and Wiener was identified as that most likely to be the appropriate spatial diversity measure and was developed into one that appeared to be more suitable for use in this thesis. A new method called the isovist gradient, inspired by the suggestions of Benedikt's isovist paths, was introduced to help visualise the concept of revelation and highlight the complexities of the revelation mechanism presented. Finally, axial revelation was defined as the change in ratio of the respective lengths of axial lines for each intersection. The total change in these values was shown to correlate well enough to consider an axial line as a large scale proxy for isovist revelation.

Key Points

The second part of the place hypothesis looks for a spatial mechanism that permits regions to have some 'spatial' identity.

This spatial identity is based on the extensive work done in environmental psychology that suggests that people have emotional responses to local environments.

Kaplan and Kaplan introduced the notion of visual mystery as a means that makes scenes 'interesting' and in further need of exploration.

This notion of mystery could have a spatial analogy in the revelation introduced by Franz and Wiener as a measure of change in isovist area.

The chapter introduced new tools and visualisations with which to map the revelation for a location.

From these, new reformulations of revelation (s-revelation) were suggested, leaving the original definitions as f-revelation.

Expanding on the suggestions of Benedikt, a visualisation of the revelation gradient was presented.

Finally axial revelation was introduced as a change in the axial 'spatial' field at junctions.

It was shown that changes in axial revelation are strongly correlated for a simple theoretical world, suggesting that axial revelation can be used as a low resolution proxy for the more fine scale isovist revelation.

Chapter 6:
Revelation in Specific Environments

Summary

This chapter takes the theory created in chapter 5 and applies it as an analytic background to an experiment conducted to measure participants' spatial awareness of place. The chapter reports on an experiment based on the work of Brettel, where participants observed two animated walkthroughs of two largely identical buildings differing ostensibly in the degree of revelation exhibited by each path. The experiment, which had 32 participants, showed that the participants appeared to be sensitive to, but largely unaware, of revelation, and typically chose the space with higher revelation as the potential location of a place (specifically a location for a café). This evidence, in combination with the previous work done, is consistent with the local part of the place hypothesis.

The previous chapter introduced the concept of revelation, while this chapter is concerned with methods to test the concept that revelation leads to "more interesting" locations.

Direct experiment

In the previous chapter Franz and Wiener's (Franz and Wiener 2005) revelation was introduced as a possible procedure to measure the local aspect of the place hypothesis. Franz and Wiener conducted tests to show that people were sensitive to isovist properties such as size and spatial structure, showing for example that people would constantly choose the same location if asked

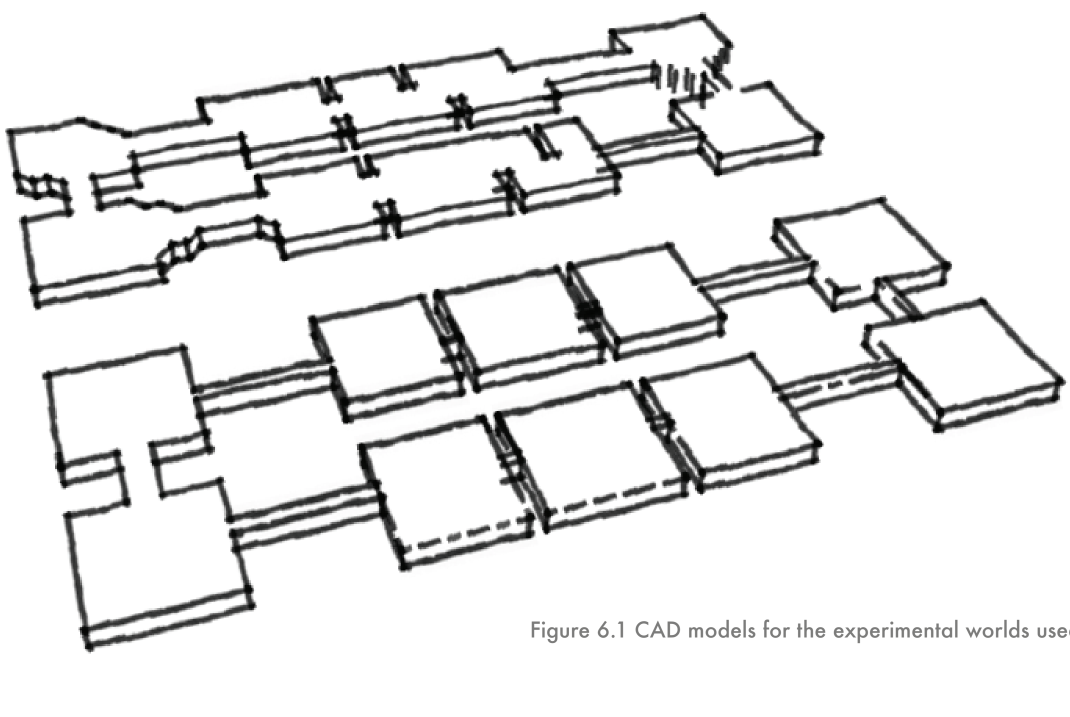


Figure 6.1 CAD models for the experimental worlds used.

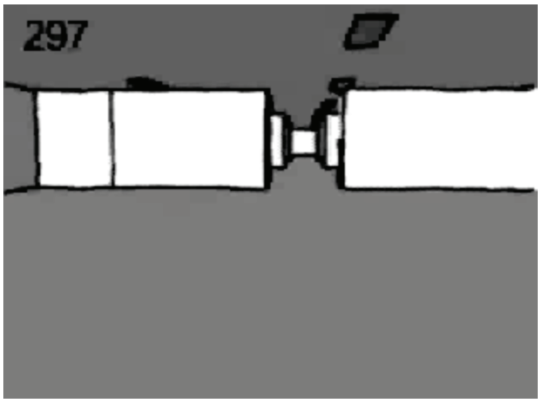


Figure 6.2 Sample frame from test movie.

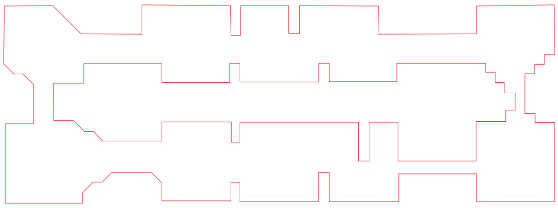


Figure 6.3 Ground plan of Level 1A.

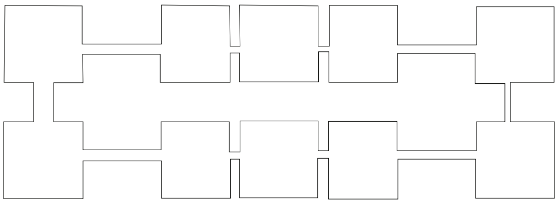


Figure 6.4 Ground plan of Level 1B.

to look for somewhere to hide and that location also had unique spatial properties. To test if pedestrians are sensitive to space through revelation as part of the character of place, a comparative test was devised. The methodology used was an extension of that used by Franz and Wiener which in turn has its roots in environmental psychology studies begun in the 1960s by Kaplan and Kaplan (S. Kaplan and R. Kaplan 1982). Kaplan and Kaplan's work was based on presenting a number of static images (photographs or slides) and asking the subjects to rate the scenes in terms of evaluations of those spaces. This became the core methodology for a number of environmental psychology studies, with Stamps (Stamps 2004) (Stamps 2000) mentioning more than 20 journal articles based on studies that used this technique, or something derived from it. It would have been simple to reproduce this kind of experiment similar to the technique used by Franz and Wiener with the addition of the comparison of the results against properties of the isovist where the photograph was taken. However, in the 1990s, Harry Heft (Heft 1996) criticised the Kaplan methodology, taking a more ecological or Gibsonian (Gibson 1986) perspective, insisting that it was the temporally structured visual information or optical flow that was the key to evaluating a scene. In his chapter, Heft provided a number of experimental results that reinforced this view. Given the movement implicit in measures such as revelation the experiment in this chapter was inspired by Heft and the work of Brettel (Brettel 2006). Brettel used a methodology where participants viewed a video over the Internet and then answered some questions about the world once the video had finished.

If a sense of place is shared tacit knowledge based on a reading of the environment (as one might expect from the work of Kaplan and Kaplan, Franz and Wiener and others) it might be reasonable to expect to find some broad constancy of behaviour between individuals. If the location of a place is related to our reading of space then it may be possible to find objective measures of space which may correlate with these notions. Thus the question became if there is no local shared reading of space which participates in a sense of place, in other words that place is purely social experience, then it should be impossible to find any constancy among participants and no relation between participants and objective measures of the shape of space.

Experimental methodology

As mentioned previously, the basis of this method was to ask participants to view two animated walkthroughs and then to decide where they might place a café in this space. The literature on place (Relph 1976, Tuan 1974) uses 'local café' as a casual icon for place. It is a familiar example and one that was thought to communicate the meaning of place effectively to the non-specialist audience. It should not be considered that a local café is not a pure proxy for place. Café location choices occur for many different reasons ranging from the contemplative to the purely utilitarian. Given the broad notions of café and the broad notions of place it would be impossible to expect the café location as probe to be a full proxy for place and as such it should be expected to have a diversity of responses. To try to remove some of the basic economic rationales for café placement (locations with high passing trade) the participants were told that the café was in a larger mall or shopping centre and that all flows were equal (no primary entrance or exit). To further limit the effects of movement the participants were told that they were looking at two floors of a shopping mall and no indication was given as to where the stairs to parking might be, further limiting knowledge of expected movement flows. To legitimise this the participants were to be told that this was a shopping mall in construction and they were the first to be invited to choose. By this means it was possible to get the participants' free choice of any space and to eliminate the influence other shops/brands might have on the decision-making process.

To try to limit the participants' reactions to only that of space, an unadorned world was created. This follows the results of one immersive (headset-based) virtual reality experiment of Conroy. In this experiment she asked participants to navigate through a virtual representation of the Tate gallery. In the experiment only the walls had any representation and those walls were a neutral white colour. One of the significant results of Conroy's work was that she showed similarity in movement patterns between the 'bare' virtual Tate Modern buildings and the real-world patterns for the original Tate Modern building. This and the work of Brettel, who also used minimal walkthroughs, shows the validity of using this low fidelity, low distraction approach when investigating the use of space on movement patterns. One of the problems encountered by Conroy in her VR experiments was the participants' disapproval of the neutrality and the difficulty of differentiating white wall from white wall of the space. To overcome this, the animation used a facility to produce a 'sketchy' rendering from a CAD program called Google Sketch Up. This sketchy presentation created a slightly more cartoon-like view, with strong bold lines for the edges. To counter some rendering problems, give a feeling of enclosure and create a strong view, the floors and ceilings were coloured a dark grey colour. See Fig. 6.2 for a single frame from the movie.

Anonymous participants were recruited to take part in an online experiment. They would visit a website and watch two videos streamed over the Internet. The participants were then asked to perform a specific task to evaluate the

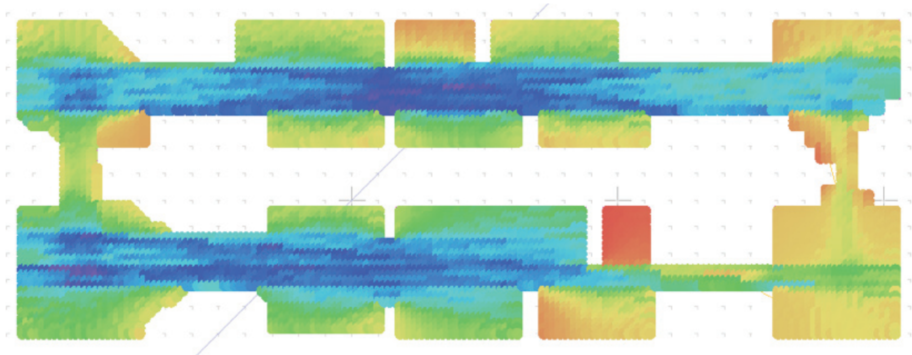


Figure 6.5 Area isovist of level 1A.

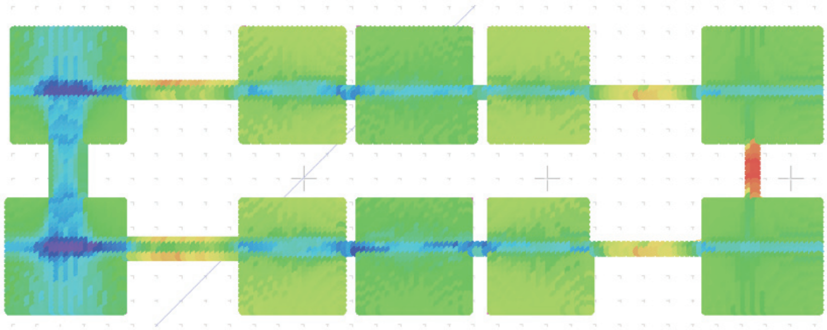


Figure 6.6 Area isovist for Level 1B.

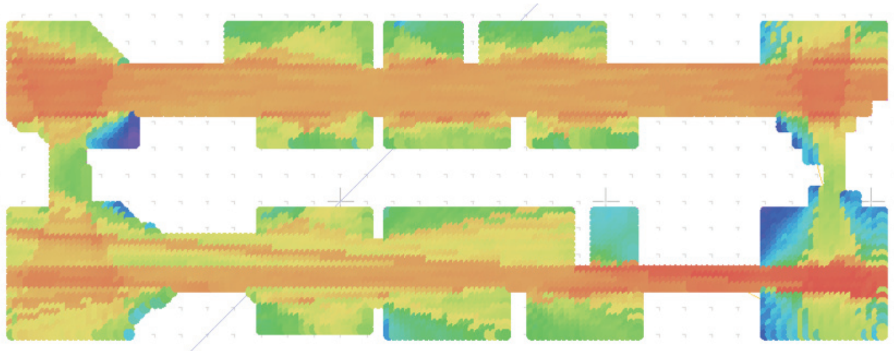


Figure 6.7 Area/Perimeter ratio, Level 1A

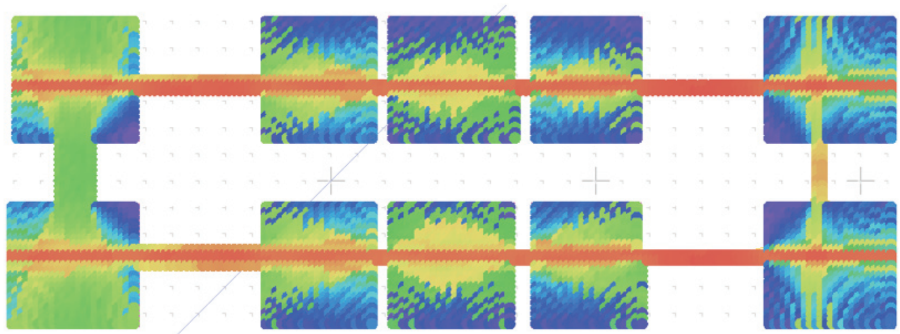


Figure 6.8 Area/Perimeter ratio, Level 1B.

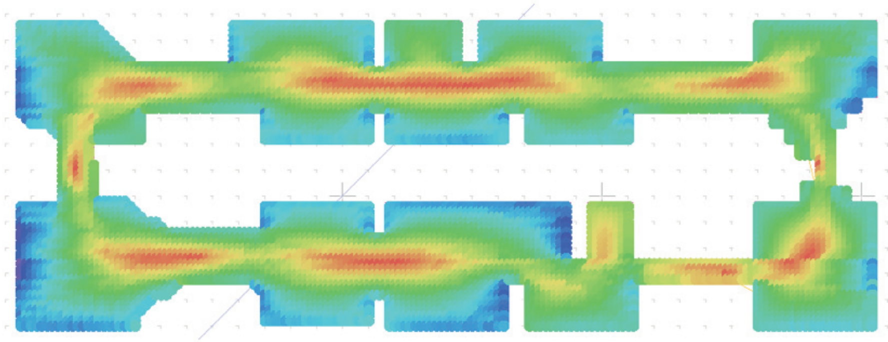


Figure 6.9 Drift Level 1A.

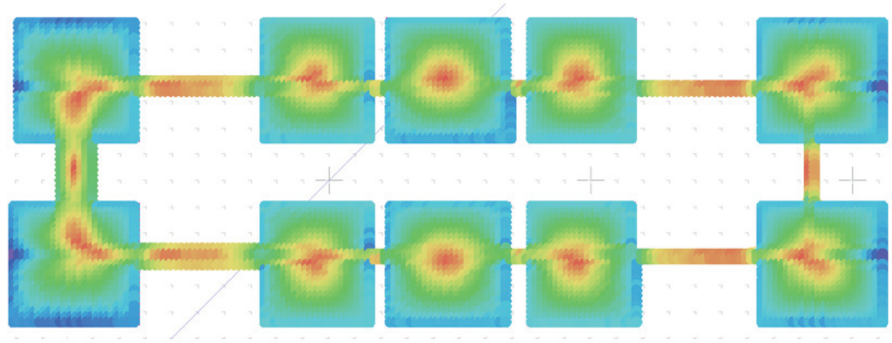


Figure 6.10 Drift Level 1B.

world and to answer survey questions to ascertain their responses to the environments. The task was choosing between one type of space or another, the results of which would then be used to assess the participants' views of how significant each building was. The results of the survey were then compared to an evaluation of a number of objective measures of space derived from an analysis of the original spatial model used to generate the videos. A comparison would also be made to ascertain whether any objective measure of space would correlate with the choices the participants made. The core hypothesis was that s-revelation would relate to the choices made.

The ground plans (see Fig. 6.3 and 6.4) inspired by the Milton Keynes shopping centre with an elongated plan forming a full circuit. Each edge of the circuit would have eight 'open' spaces (see Fig. 6.1). The plans were constructed so that they would cover the same area but also have the same axial model and give a moderately similar convex model. Thus, given the same spatial model, it is possible to attribute the results to just the local properties of revelation rather than to the global properties of the configuration of space. One building was designed to generate stronger revelation points, while the other was designed with smoother transitions.

Both buildings were subjected to a gridded isovist analysis - see Turner (Turner et al. 2001) and Conroy and Dalton (Conroy Dalton and N. Dalton 2001), with a facility of the Interstice (N. S. Dalton) program created for this research and included on the attached media. We can see from Fig. 6.5 and Fig. 6.6 above that while the general configuration is highly similar (two rows of five 'spaces' pierced by corridors with links at either end) that the area's gridded isovist emerges as highly dissimilar. The colour scheme here is inverted, with the largest isovists being coloured blue and the smallest being coloured red. It should be noted that the values displayed are internally relative; that is, the value of red is the smallest value within the building and the blue is the largest. Also, the colours of the processed models cannot be compared. In this case, the absolute values are a mininum area of 849.8 and a max area = 8786.3 for level 1A and a minimum area of 790.4 and a max area of = 4365.2 for level 1B. Note that these values are the ranges for the isovists, not for the system as a whole. We can see in Fig. 6.6 that the largest (bluest) available isovists are horizontal across the building, with another broad one to the left of the building plan. In both cases, the right hand side holds the smallest isovists.

In Fig. 6.7 and Fig. 6.8, we see quite a pronounced difference between the distributions of the area perimeter ratios. Area perimeter ratio is suggested by Benedikt, but is here implemented as the area divided by the perimeter squared. The process of dividing by the square makes the value a ratio, or dimensionless number. If this is not done, the value of the area divided by the perimeter becomes a value per unit area measure and cannot be thought of as truly allowing for the natural increase in area for a given perimeter. In the figures above, the values change from red as mostly spiky to blue as mostly round. We can see that the highly square rooms are quite pronounced and their absence shows up as a general green colour in Fig. 6.7. It can also be observed that both buildings are roughly horizontally symmetric, giving no strong differentiation between the top and bottom corridors.

The absolute values are min A/P2 of 0.004508, max A/P2 = 0.0693 for level 1A and A/P2 of 0.002908, max A/P2 = 0.065659 for level 1B, suggesting that the values are similar.

Drift was a measure introduced by Conroy and Dalton (Dalton and Conroy 1999; Conroy, Dalton and Dalton 2001) as a method to measure the eccentricity or asymmetry of a space. Mathematically, it is a measure of the distance (vector can also be used) between the centre of the generating isovist and the centre of gravity of the shape. In Fig. 6.9 and Fig. 6.10, we can see the typical pattern of drift - with it being the smallest in the centre of a space and largest at the edges. A comparison shows that the range of actual values are quite similar, with a minimum value of 0.0951 and maximum value of 20.341 for Level 1A and a minimum value of 0.0503 and maximum value of 16.6219 for Level 1B.

We can see from Fig. 6.11 and Fig. 6.12 that the maximum radius value is practically identical for both spaces (as we would expect, given that the spaces are alike in purely overall geometric terms).

There is a min maximum radius of 36.557 and a maximum value of 332.608 for Level 1B, and a minimum maximum radius of 33.710 and maximum maximum radius of 330.710 for Level 1A. We can see from these figures that we are looking at a distribution of values rather than any simple gross geometric effects.

Fig. 6.13 and Fig. 6.14 show that while the buildings exhibit similar results along the corridor lengths, a unique space is created on level 1A in the lower part of the level in the closed area to the right. The values of the colours represent a minimum value of 7.3559 and max value of 33.81571 for Level 1B, and a minimum value

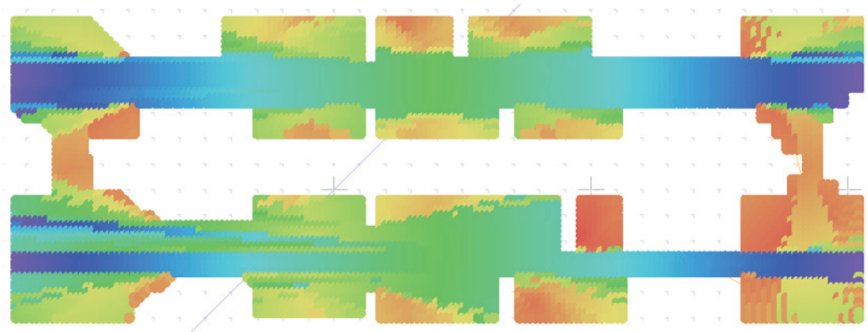


Figure 6.11 Maximum radius Level 1A.

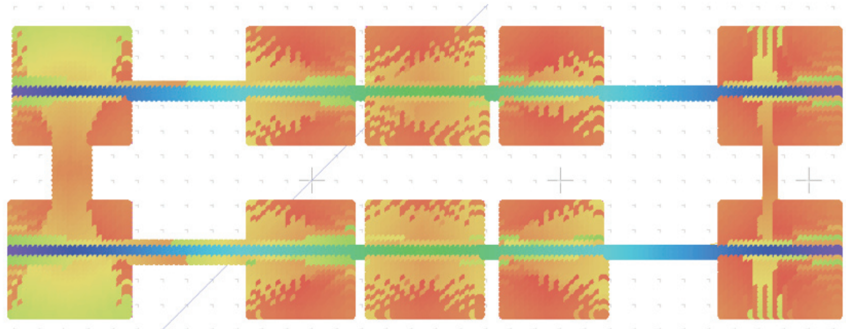


Figure 6.12 Maximum radius Level 1B.

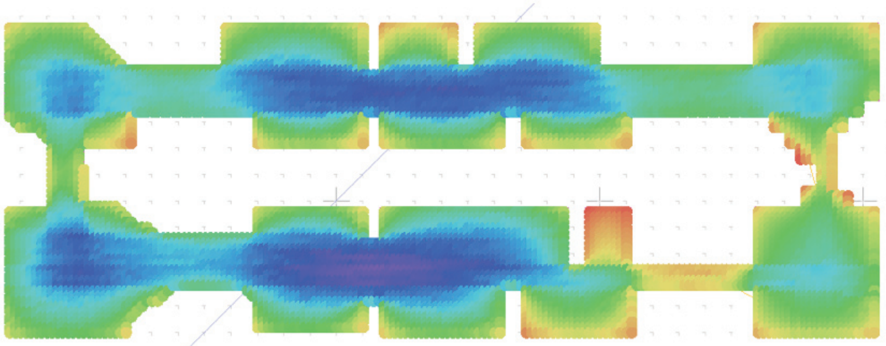


Figure 6.13 Average radius Level 1A.

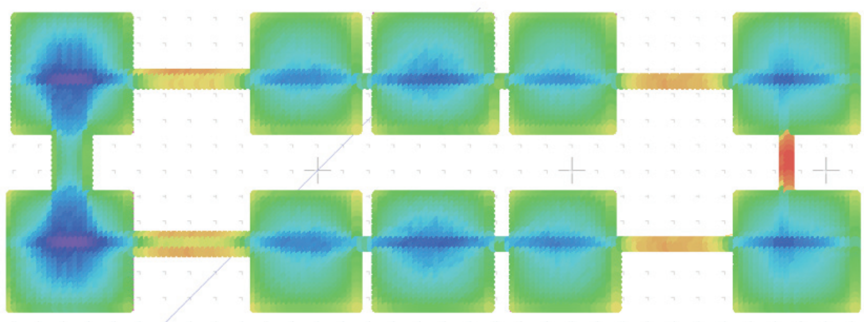


Figure 6.14 Average radius Level 1B.

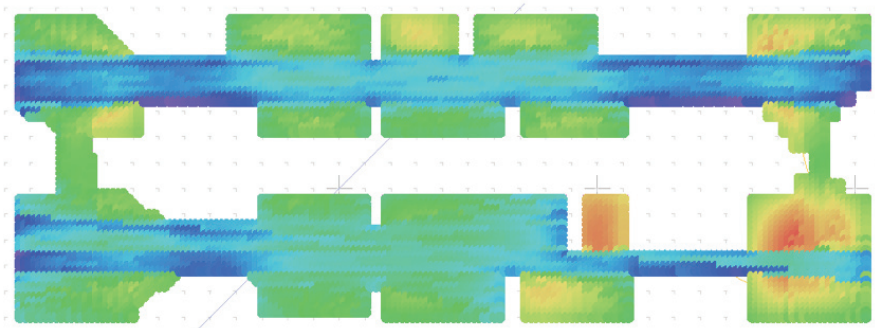


Figure 6.15 Standard deviation of radials, Level 1A.

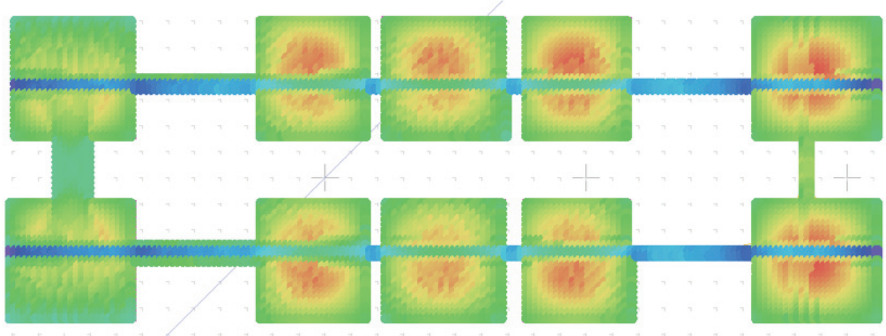


Figure 6.16 Standard deviation of radials, Level 1B.

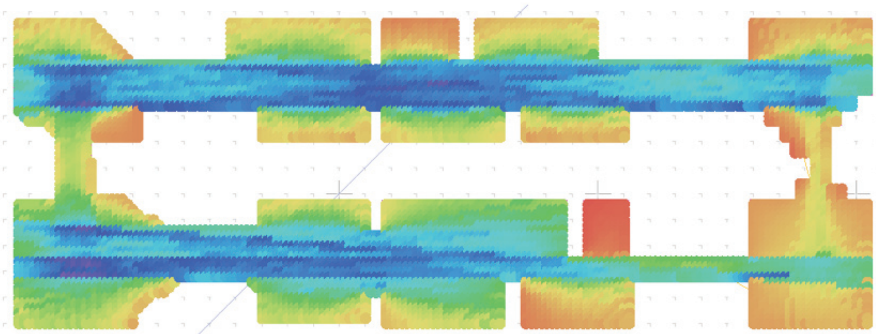


Figure 6.17 First Hu moment of radials, Level 1A.

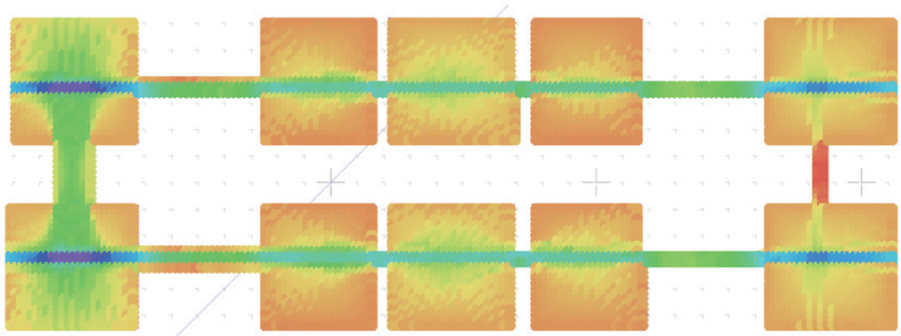


Figure 6.18 First Hu moment of Level 1B.

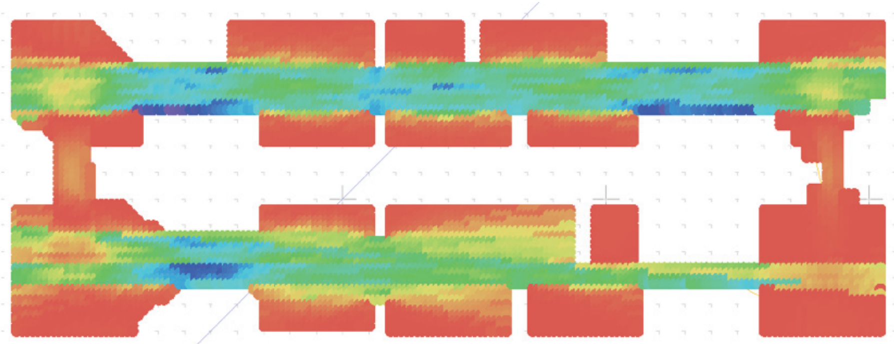


Figure 6.19 Second Hu moment, Level 1A.

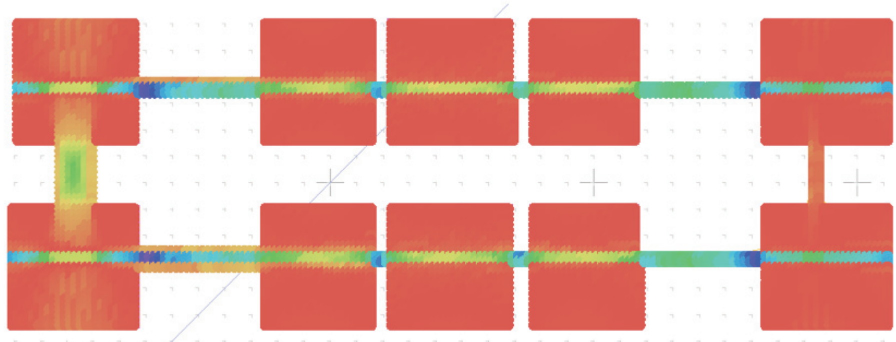


Figure 6.20 Second Hu moment, Level 1B.


Figure 6.21 Third Hu moment, Level 1A.

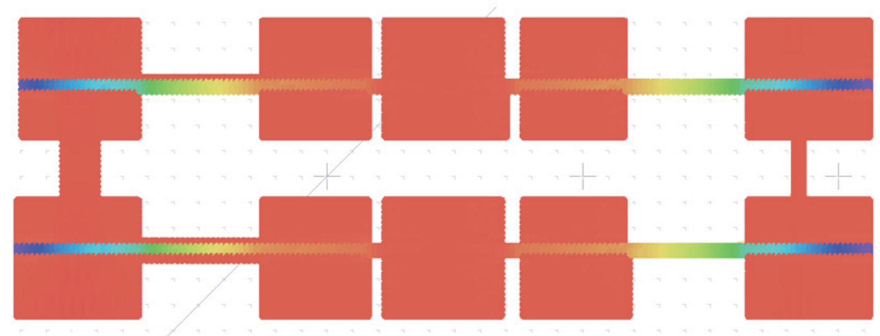


Figure 6.22 Third Hu moment, Level 1B.

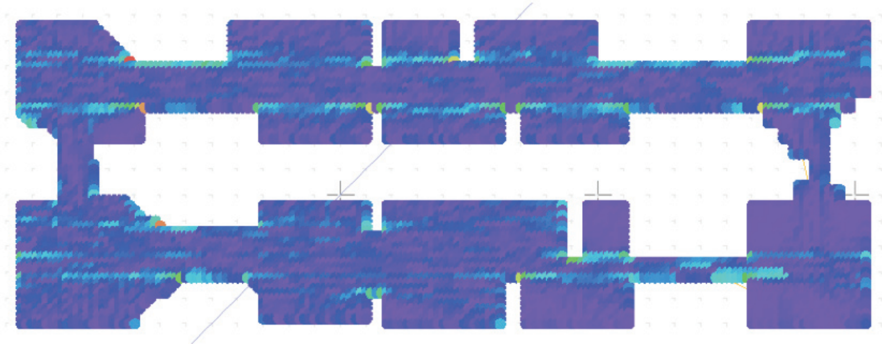


Figure 6.23 Map of Revelation, Level 1A.

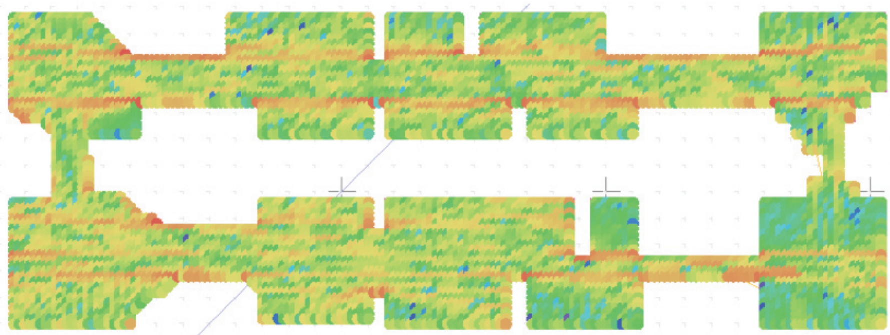


Figure 6.24 Map of Log of Revelation, Level 1A.

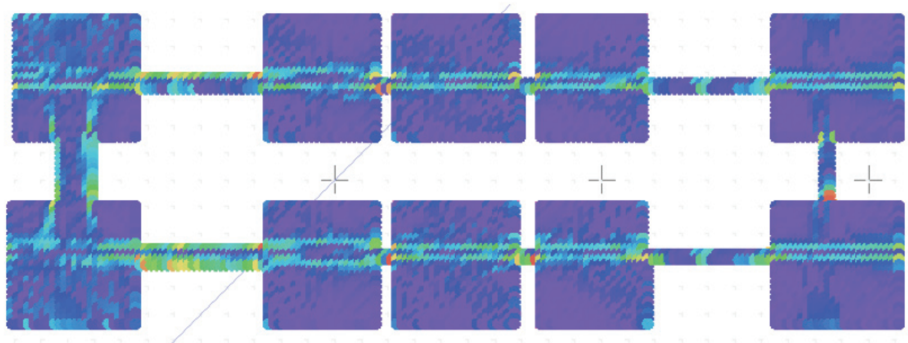


Figure 6.25 Map of Revelation for Level 1B.

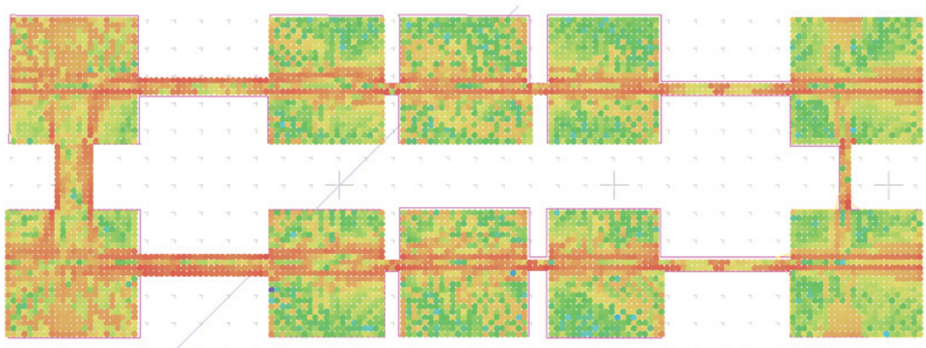


Figure 6.26 Map of Log Revelation, Level 1B.

of 9.89262 and max value of 42.87208 for level 1A.

We see the uniqueness in terms of the small room in level 1A repeated in the map of the standard deviation of the radials (see Fig. 6.15). Clearly, the long axis is a point of maximum standard deviation of the radials.

With a minimum value of 6.389 and a maximum value of 46.302 for Level 1A, and a minimum value of 7.356 and maximum value of 33.816 for Level 1B, the values appear reasonably close (see Fig. 6.15 and 6.16).

Most of the measures presented by Benedikt are measures of the 'shape' of a space; in the world of image processing, there are a number of standard mechanisms by which to apply area, orientation and translation independent measures of the shape of an object. These Hu (Hu 1962) moments are used in a number of fields to assess and recognize the shape of an object. In applying the first Hu moment to the gridded isovists of both planes, we see the same kind of broad differences as we saw in the area perimeter ratio above (to which the Hu Moment is related) (see Fig. 6.17 and 6.18). It is interesting to observe that when the differences between a corridor and room are strong, as they are in Fig. 6.18, the First Hu moment appears to be picking out the axial structure of the building.

Minimum Hu moment = 20817.5019 maximum Hu moment = 280324.6875 for Level1A

Minimum Hu moment = 27829.2792, maximum Hu moment = 195164.2969 for level 1B.

In Fig. 6.19 and Fig. 6.20 above, we can see a stronger picture than the first Hu moment, picking up the axial structure again.

Min value = 64.330, max value = 5.309E10 for Level 1A.

Min value = 7.9202E–4, max value = 1.5651E10 for Level 1B.

In Fig. 6.21 and 6.22, we see the third Hu moment, almost exclusively picking up the axial structure again.

Level 1A - Min value = –1.1475E13, max value = 2.6430E15

Level 1B - Min value = –1.1880E13, max value = 1.0205E15, which looks comparable.

Revelation Max = 1057.6854, min value = 0.03108.

Finally, maps of the s-revelation were computed. These were the eight-way revelation, divided by the number of nodes (to allow for nodes at the edges that were not eight-way connected). Fig. 6.23 and Fig. 6.25 show the value of revelation plotted as colours. As we might expect in a near open space, the transition from one point in space to another produces little change in revelation, leaving most of the image blue (near zero value). Points of high (orange-red) revelation clearly occur near the edges of the doorways or openings, forming strong T space markings in both systems. In both buildings, narrow passageways give points of medium to high revelation as one emerges from the passage and enters the space.

Fig. 6.24 and Fig. 6.26 above show the values (colour range) compressed by mathematically taking the logarithm of each point; from these we can see some of the low-end differentiation of space. It should be noted that in the logarithmic case, we are seeing the effects of a tenth decimal place comparison, so the deep blue points are due to the accuracy of computation rather than showing any significant change in the isovist.

It should be noted that the figures produced above are, again, internally normalised; that is, the colour range reflects that of the range of the individual plans/level, it is not relativised over both plans/levels. If we look at the range of the values, we see that in the case of Level 1A, the maximum value of revelation (the maximum change in isovist areas) is 1057 (pixels), as compared to 257 in the Level 1B case. That is, the change from one space to another is quite considerable in the case of Level 1B but the spaces that we emerge into are smaller than in Level 1A; therefore, the value of revelation is larger in the case of Level 1A.

Empirical testing

The experiment was based on a web page presented at www.thepurehands.org/tombq and a copy of the website is on the accompanying DVD-ROM. In the experiment, the following text was used to ask participants to identify a spot in a shopping centre in which they would locate a café.

> *'You are going to give up your job and do what you always wanted to do and set up a hip, cool, stylish café. You are invited to set up your café in a new mall containing two floors. The mall is currently at construction stage and you have a completely free choice of where to locate your café. The mall has two floors and the location of your café will help drive the decisions of where the 'cool' shops will go. There are multiple entrances so there is no single location that is better connected compared to any other.*
>
> *You want to create a unique 'place': somewhere people will recommend to others and deliberately*

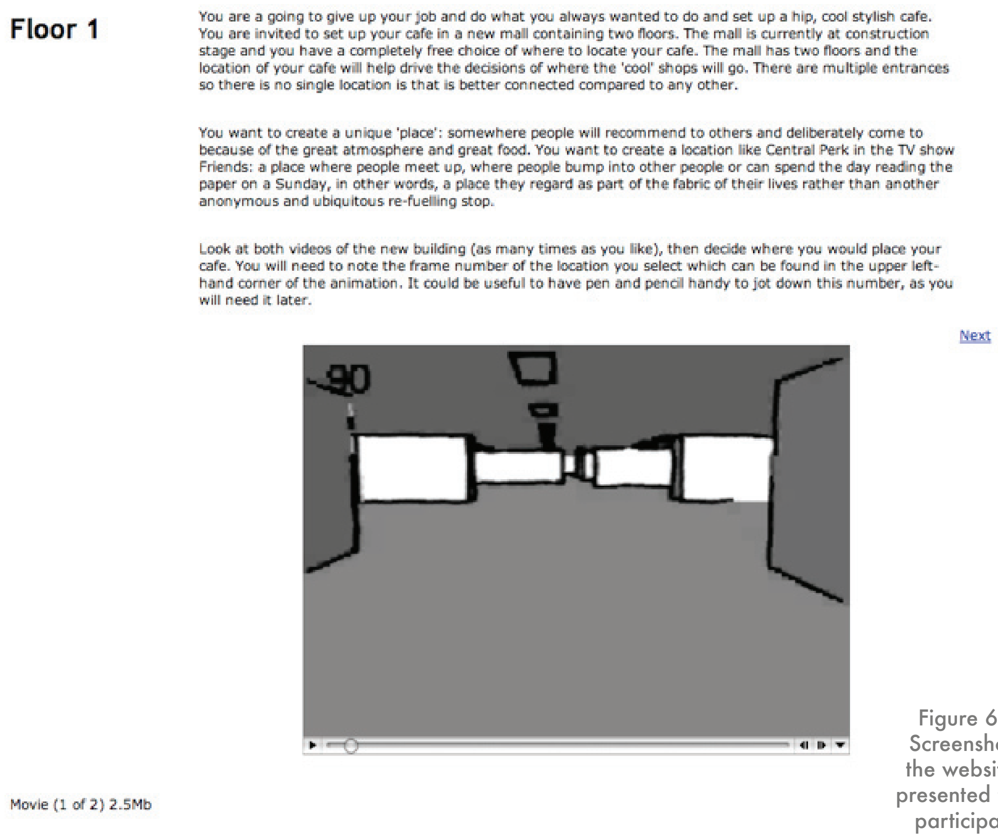


Figure 6.27 Screenshot of the website as presented to the participants.

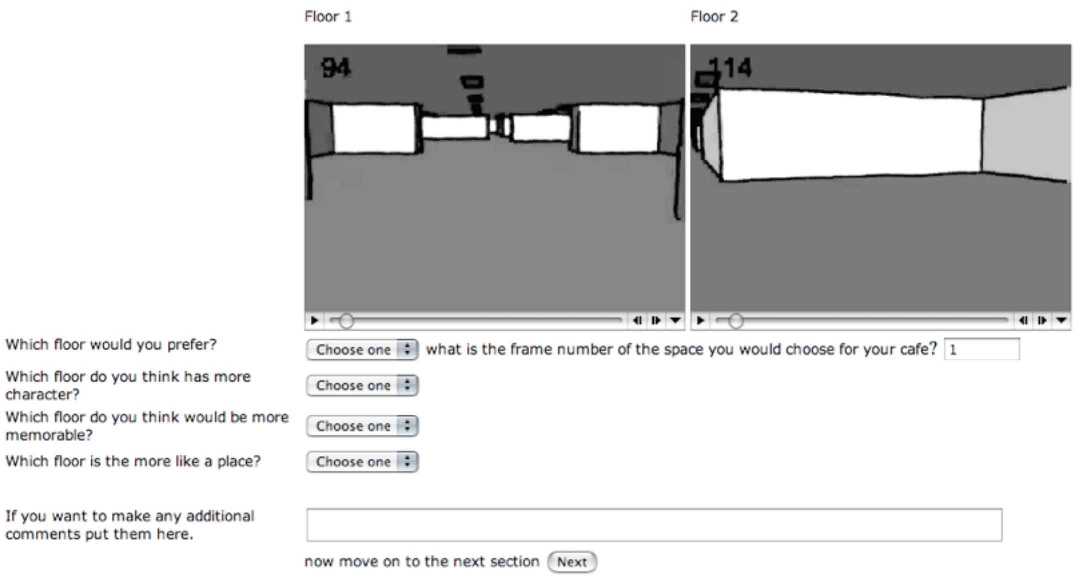


Figure 6.28 Questionnaire and review animations.

come to because of the great atmosphere and great food. You want to create a location like Central Perk in the TV show Friends: a place where people meet up, where people bump into other people or can spend the day reading the paper on a Sunday. In other words, a place they regard as part of the fabric of their lives rather than another anonymous and ubiquitous re-fuelling stop.

Look at both videos of the new building (as many times as you like), then decide where you would place your café. You will need to note the frame number of the location you select, which can be found in the upper left-hand corner of the animation. It could be useful to have pen and pencil handy to jot down this number, as you will need it later.'

The participants were asked to find the point in space and the floor or level that they would choose for their café. The café location scenario was used for a number of reasons. First, although the location was not the core question, it would encourage the participants to try to assess the environment. Second, the location of the café would indicate any spatial regularity in the worlds. The key test here was whether the degree of revelation influenced the choice of location. The use of the descriptive text was inspired as an attempt at a positive description of place. That is, it was an attempt to describe somewhere that was not placeless in the Relph sense. The text was designed to eliminate the concept of a general starting or ending location.

Once the participant had viewed both floors (see Fig. 6.27 for a screen shot of the webpage), they were presented with the questionnaire in

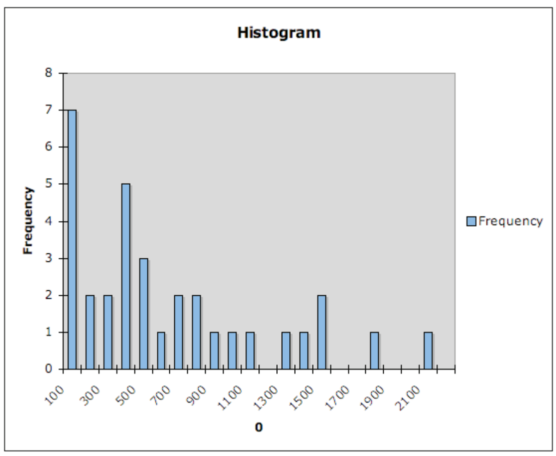


Figure 6.29 Histogram of frequency distribution of reported locations of café.

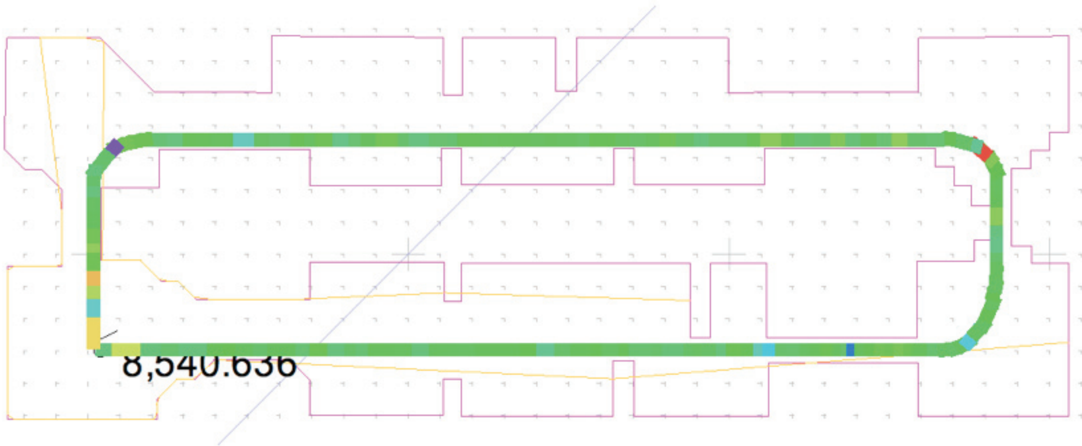


Figure 6.30 Area isovist of path for Level 1A.

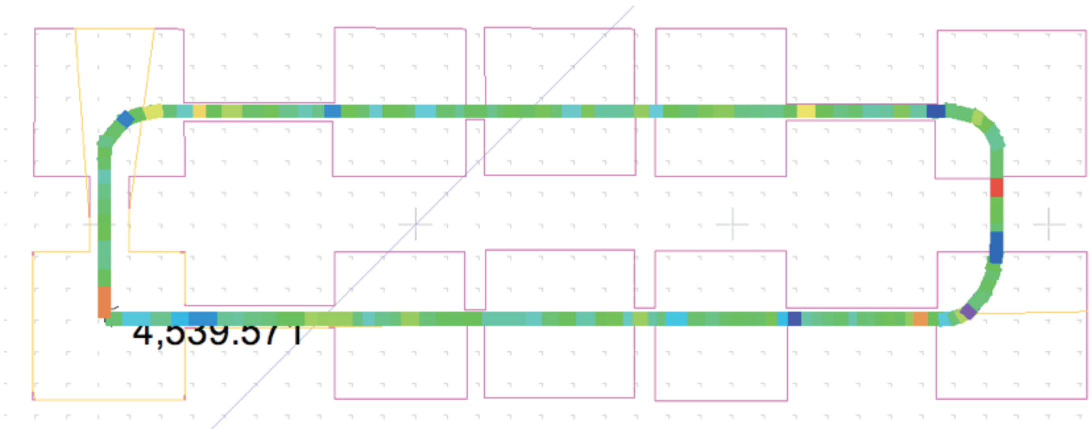


Figure 6.31 Area isovist of path for Level 1B.

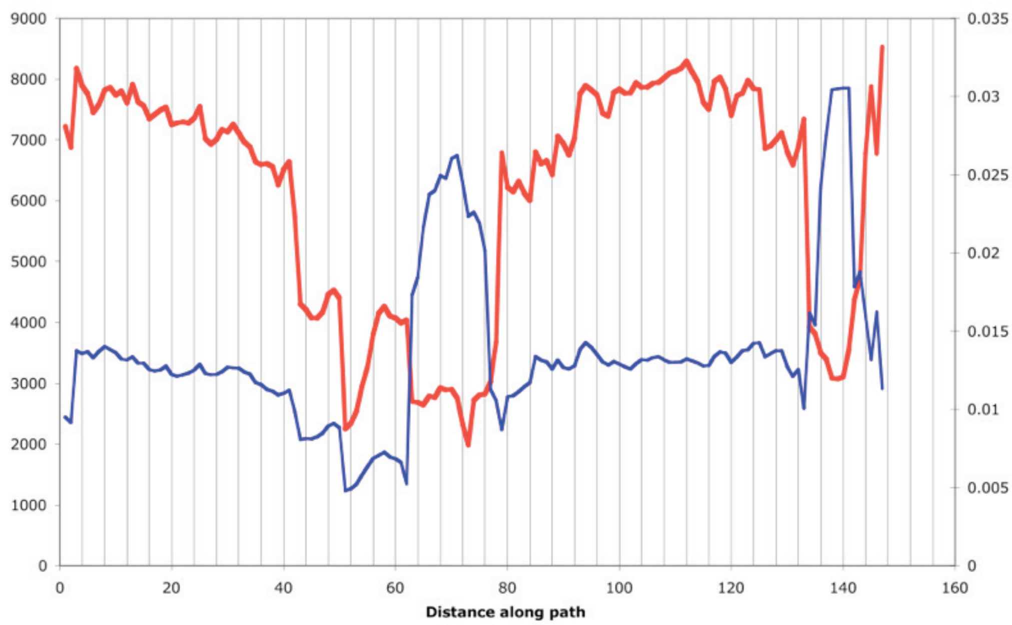


Figure 6.32 Plot of Path Isovist Area (red) and Path Isovist Area/Perimeter 2 (blue).

Result	Which floor pre-ferred?	Location	Floor memor-able?	Floor-Char	Floor-Place
R1001	1	1401	Neither	3	3
R1002	1	470	1	1	1
R1003	1	362	1	1	1
R1004	1	1071	1	2	3
R1005	1	433	Neither	1	1
R1006	1	865	Neither	3	3
R1007	2	1	Neither	2	2
R1008	1	253	1	1	1
R1009	2	1721	1	2	2
R1010	2	348	2	2	2
R1011	1	170	1	1	1
R1012	1	1000	2	1	3
R1013	1	120	Neither	1	1
R1014	2	582	2	2	2
R1015	1	460	1	1	1
R1016	1	2019	Neither	2	1
R1017	1	1350	1	1	3
R1018	2	971	1	2	2
R1019	1	660	1	3	3
R1020	1	320	1	1	1
R1021	1	780	Neither	1	1
R1022	1	509	2	2	2
R1023	2	75	Neither	2	3
R1024	1	303	1	1	1
R1025	2	1227	2	3	2
R1026	1	1299	1	1	1
R1027	1	1499	1	3	1
R1028	2	969	Neither	3	3
R1029	1	670	1	1	1
R1030	1	230	Neither	2	1
R1031	2	507	2	2	2
R1032	1	1721	1	1	1

Table 6.1 The responses from the online experiment.

Fig. 6.28. This presented both videos again to permit the participant to review and compare the worlds directly.

The participant could then choose one of the popup menu options and enter the frame number of the point in the animation that they preferred as their café location. The following questions were asked:

- Which floor would you prefer?
- Which floor do you think has more character?
- Which floor do you think would be more memorable?
- Which floor is the more like a place?
- If you want to make any additional comments put them here.

The results were then collected by a PHP script and emailed to the author. The order of the animations may have been an influential factor and this was handled by periodically changing the code to alter the order in which the animations were presented. The small amount of publicity only produced 32 valid responses, along with 7 that were apparently incomplete (for example, not giving a location number for the café). The results of the questionnaire are presented in Table 6.1 below.

It can be seen from the table that 23 participants chose the Level 1A and only nine returned a value for the level 1B floor. This appears to be a non-random distribution clearly favouring Level 1A. Level 1A was also the preferred option for being more like a place (16 responses for level 1A, 8 for level 1B with one failure to set and eight votes for neither). For character, level 1A was also ahead (15 for level 1A, 11 for level 1B), although the responses about character were closer to that of a random sample, suggesting that the question was loaded with jargon and so uninterpretable, or that people might have been judging on some non-spatial basis that was clearly excluded from the experimental set up.

While the location of the café is not relevant to the analysis, the distribution of locations is interesting in that a cluster of responses are reporting that early locations are more favoured

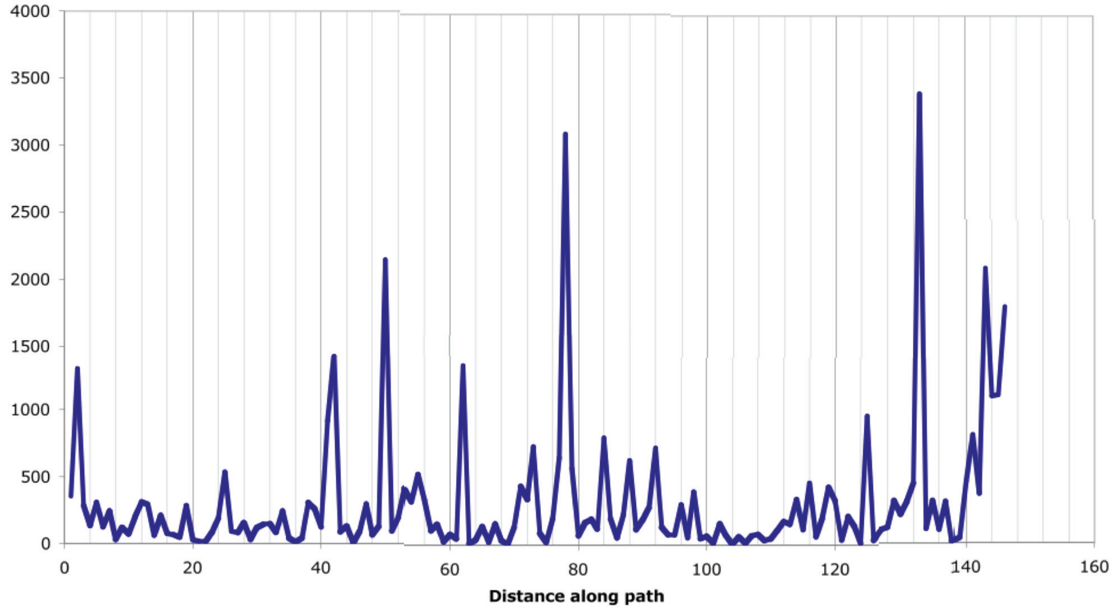


Figure 6.33 Plot of revelation along line level 1A.

as a starting point (see Fig. 6.29) This suggests that many were 'reading' the space in the same way.

The experimental setup focused on looking down one predetermined view in the animation. From this, we can create a path isovist (Conroy 2001) and compute both a table and a chart of values.

Looking at Fig. 6.30 and Fig. 6.31, we can see the path of the camera that has been superimposed onto both maps. The path is identical for the two cases, as was the case in the animation, but the pause points were removed to permit a simpler visual comparison – the isovists are unrestricted 360 degree ones that would not change if the camera was panned, as the animation was. The values for the isovist were computed for the path and these values are presented in Fig. 6.32. We can see graphically in this figure what we can see in Fig. 6.30: that the corner spaces are the areas with the most changes in area (i.e. revelation). Given that the path is known, it is possible to compute a new type of path revelation. Path revelation is the computation of revelation along a path, in which only the current and previous points are considered (rather than the changes in all of the cardinal directions) (see Fig. 6.33).

If we compute the sum of absolute changes in isovist area, we have the total revelation for a path; in the case of Level 1A, this value is 45738 square pixels. For level 1B, the value is 34038 square pixels; a comparable level can be found by repeating this process with slight changes in the path location and segmentation, with a nearly 34% increase in path revelation for Level 1A against Level 1B. This finding reinforces the results for the gridded isovist revelation above, as seen in Fig. 6.23 and Fig. 6.25, while the values look comparable, with a larger change in area occurring in Level 1A over Level 1B. With this, we can conclude that for the path revelation, the level 1A path encounters more revelation than level 1B.

The result of this objective measurement of space should then be compared to the results of the questionnaire: that level 1A was a more likely choice than level 1B. This work reinforces the findings of Franz and Wiener (Franz and Wiener 2005), suggesting that there is a correlation between spatial behaviour and experience. It also provided evidence consistent with the theory that people are implicitly, but consciously, aware of revelation when assessing the character of a space.

Conclusions

This chapter introduced an experiment where people were asked to find a space with more 'character' for a hip or rather non-placeless café. The results showed that respondents favoured a space with a larger change in revelation when all of the other factors were constant. This result is consistent with the assertion that pedestrians are aware of local changes in space and respond to them when considering the 'feel' of a place. Thus, there is evidence to support the place hypothesis, which requires that space be both meaningful and recognisable. In this regard, it is suggested that informational changes in revelation influence the difficulty of identification. While less sensitive, the four sites used in the case study indicated that urban and suburban spaces do show comparative differences and similarities across a group and between groups. This is indicative that the local character local is reflected in the ordering of local spatiality.

Key Points

An online experiment using a largely spatial description of space was used to determine the location that people would choose for a café, from two buildings. This returned a strong agreement that the first (Level 1A) space was the preferred, more interesting and more hip location.

In performing a path revelation computation on the path used to generate the videos for the experiment, it was possible to show that the path with the larger degree of path revelation was the one that was chosen by the participants as the favoured location.

This experiment, and others carried out in the literature, support the second part of the place hypothesis: that locations with paths showing larger changes in spatial characteristics, such as revelation, are more strongly identified as places.

Chapter 7:
Revelation of Case Study Areas

Summary

This chapter concludes the process of revelation bringing it in amalgamation with the neighbourhoods used in the following chapter. Clearly to be effective revelation as a measure needs a parameter indicating of what size of area it is being applied to in order to get a value for 'total revelation' for an area. As will be shown in a later chapter the area of a neighbourhood can be found using the point synergy methods outlined or the reported consensus neighbourhood from the following chapter it is possible to discover the revelation measures for a number of sites. This chapter goes on to apply axial revelation to all three test areas and an area of Barnsbury in London. The chapter then shows that the total axial revelation per line for the suburban centres is 8.9 and 7.37 while for the urban centres it is 10.4, 10.6. Thus it appears that total axial revelation is reporting something about the kinds of place (urban, suburban) that it is measuring. The chapter ends with the observation that this is consistent with the place hypothesis.

Reapplying revelation

So far we have seen that revelation can be measured to influence our perception of what makes a place unique. This assumed that the area of the neighbourhood which would be vital to define the area of interest was known. The thesis will show in the following chapters that at the large scale it is possible to find the neighbourhood using synergy and this area is strongly connected to the consensus area (see Fig. 7.1) which is the zone reported by participants in the neighbourhood finding methodology. Given that the area which defines a neighbourhood can be known in a non-arbitrary way, it is possible to process the revelation measures for a neighbourhood to see if there is anything about the spatial characteristics that tend to define them. In this case the areas are too large to process a gridded or stochastic isovist revelation map and it makes more comparative sense to apply the axial revelation process to the axial maps prepared for the test areas in the following chapters. From the revelation theory chapter it is understood that axial revelation is a low level proxy for the higher resolution isovist revelation process. Thus we would expect to see some broad brush aspects of what makes an area more interesting than another to appear from this analysis.

Case Studies

The previous revelation experiments suggested that area with higher cumulative revelation would be ones which be perceived of as more interesting and with a higher degree of character. Translated into axial revelation terms this would suggest that we would expect higher levels of total revelation for vibrant urban areas rather than the suburban areas. By processing

Figure 7.1 Axial neighbourhood (orange) retrieved from consensus map.

the axial maps all taken from the same larger scale axial map of London the values for relation should reflect the changes in urban configuration rather than changes in scale. This was done for each of the areas taken below. Boston, while having a known neighbourhood area was excluded due to the axial map being at a different scale from the others and the effects of a different spatial and historical cultural process on the configuration of space is unknown. Barnsbury was substituted using the boundary in Hillier & Hanson (Hillier & Hanson 1984). This boundary was very strong and in good accord with the boundaries attributed to the neighbourhood it was felt viable to include the neighbourhood in Barnsbury as one of the case study areas as an example of an inner city neighbourhood. The Barnsbury map was at the same scale and cultural background as the other case studies making for a useful comparison.

Four case studies will be presented that examined two urban and two suburban areas. The theory being that the urban will have more 'character' via revelation and the suburban ones will be more uniform and so be perceived of as less 'exciting' an idea intended to reflect the typical assumptions about suburbia. Again the hypothesis that is really under test is that place is divorced from the spatial character or that space[1] and place are unrelated. The first case study will be of a vibrant area called Islington/Barnsbury in London (included for the reasons mentioned above). The second urban environment is that of Clerkenwell. Finally there will be two suburban locations, those of Hampstead Garden Suburb and Bretham Garden Suburb. For this comparison it would seem natural to consider these as two urban and two suburban locations. Certainly after visiting each neighbourhood it appears that they all conform to their respective stereotypes. Barnsbury and Clerkenwell are vibrant,

1. In the syntactical sense.

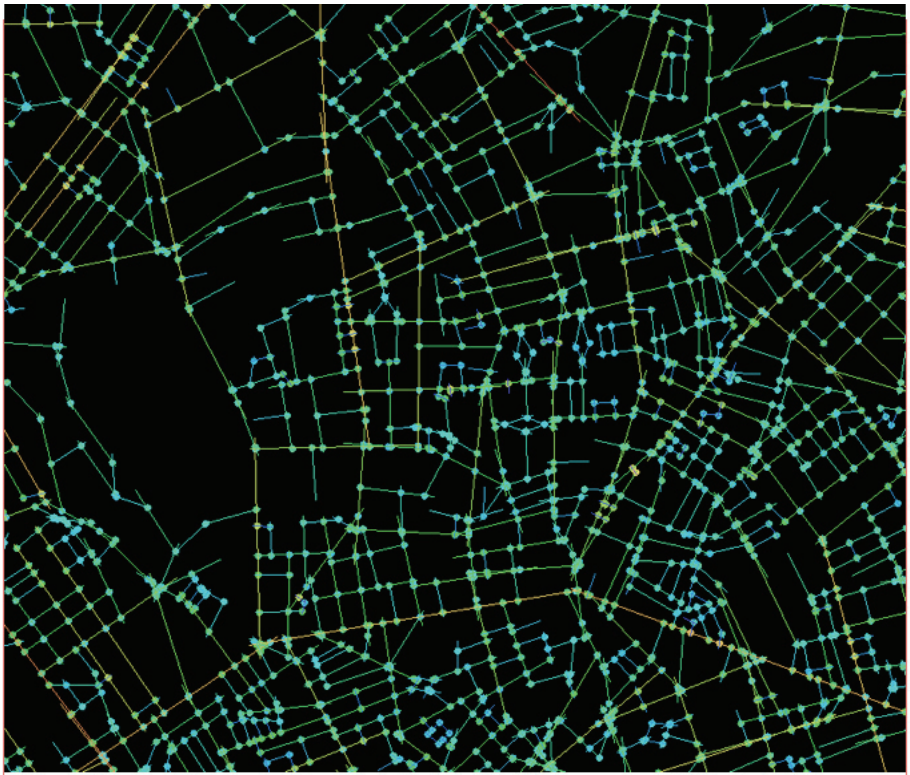


Figure 7.2 Islington/Barnsbury plotting line length ratio. Axial lines plotted by logarithm of line length.

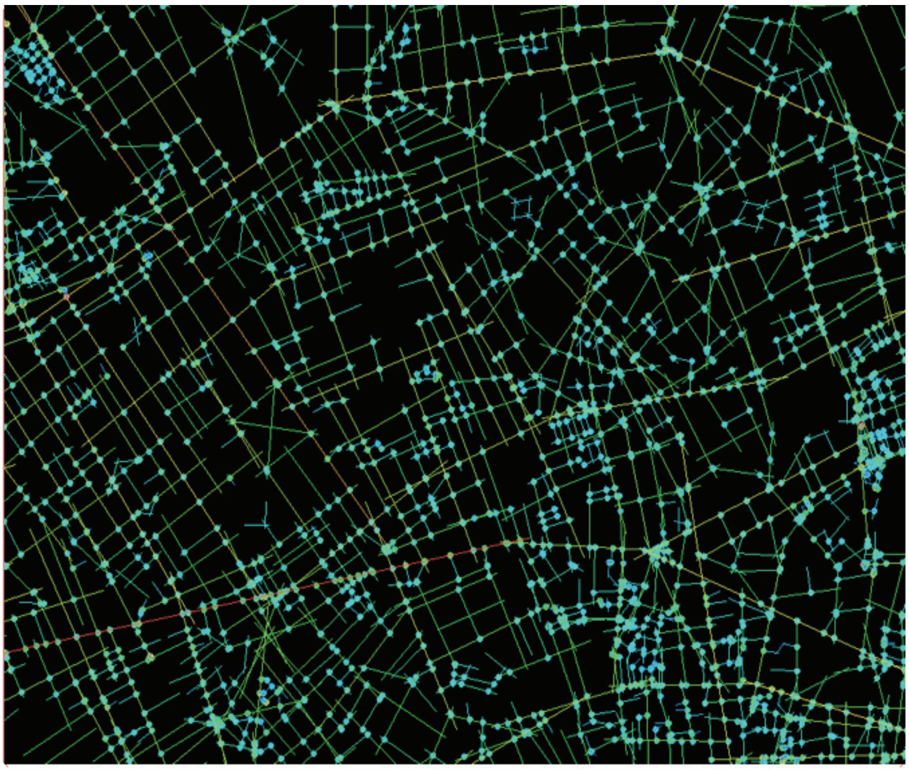


Figure 7.3 Clerkenwell plotting line length ratio. Axial lines plotted by logarithm of line length.

busy, almost noisy, anonymous, cosmopolitan, bustling urban locations with large numbers of facilities and a strong mix between wealth and poverty. Both garden suburbs feel quintessentially suburban, quiet, calm, leafy, friendly, safe places to bring up children. It is these kind of impressions which help to form our notion of *genius loci* leading to place. It is this which will be used as the yardstick against which the results of the revelation analysis will be made. In each case the area processed by revelation is the one returned as the consensus neighbourhood which is felt to be a best extent of the place.

Islington/Barnsbury

Barnsbury and the associated area of Islington have a long history of analysis in space syntax being presented in *The Social Logic of Space* (Hillier and Hanson 1984) and *Space is the Machine* (Hillier 1996) among many other works and is as such a very familiar area. The axial revelation maps presented in figure 9.2 show a large number of active high revelation connections. In this environment one is constantly turning from one street to a much larger or much smaller one.

Clerkenwell

Clerkenwell (see Fig. 7.3) was chosen as an area that was diverse with considerable history and character. Indeed the area was so well regarded that it was used as an example of a successful urban area by the Urban Village Movement (Franklin and Tait 2002). Clerkenwell had also undergone considerable spatial study at the time of the initiation of this thesis and was thought to be well known. Hampstead Garden Suburb was also a previously studied area, having been surveyed by the space syntax group.The revelation area chosen was that for the consensus neighbourhood found in the following chapter. The axial maps below show the associate values for the neighbourhood of Clerkenwell. As with Barnsbury we can see a large degree of change from axial line to axial line.

Hampstead Garden Suburb

The axial map in figure 7.4 shows the line length revelation for the centre of this region.

Hampstead Garden Suburb was felt to be both a well ordered and well studied suburb, being used both on the space syntax undergraduate course and as the basis for a PhD thesis by Kim (Kim 2001) (Kim and Penn 2004) about wayfinding and cognitive maps in space syntax. it is possible to see some points of very high revelation change (red and orange near the top); these are points outside the neighbourhood of study. From the axial revelation map, the change in revelation appears to be highly uniform but this would be a misperception. What makes this system interesting is that there are practically no points of low revelation (intersections without an intersection indicator). Hampstead Garden Suburb will be more fully introduced in chapter 10 and is the first of the two truly suburban areas studied. The area covered is very large in comparison with some of the other study areas, but like Brentham Garden Suburb below is also a primarily domestic area with retail in some areas. Like Brentham Garden Suburb the domestic stock is mostly semi-detached creating the strong impression of leafy suburban living. While the visualisation does not betray this the total revelation change per line is quite low (low green

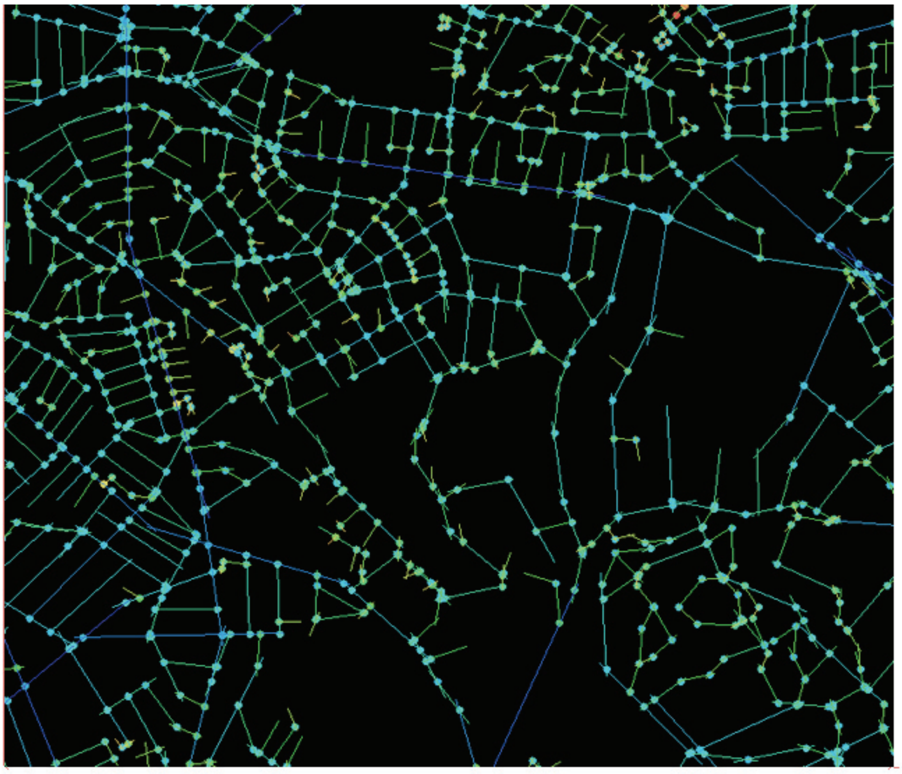


Figure 7.4 Hampstead Garden Suburb plotting line length ratio. Axial lines plotted by logarithm of line length.

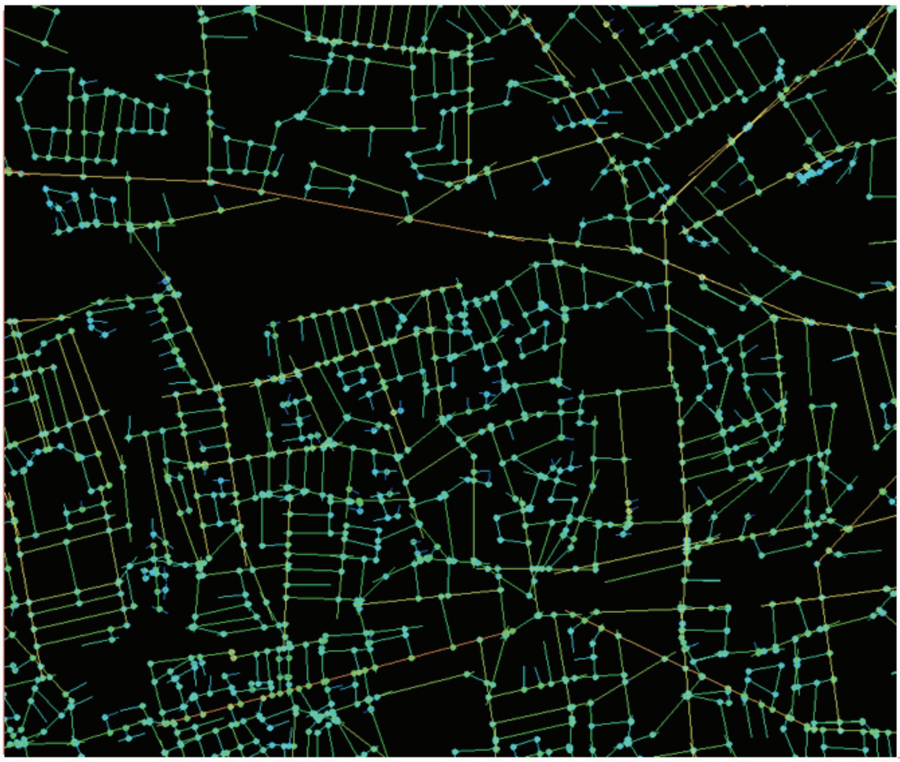


Figure 7.5 BGS plotting line length ratio. Axial lines plotted by logarithm of line length.

Area	Intersections	Lines	Ratio rev	Rev/line
HGS	792	256	2286.1	8.930186677126270
BGS	166	53	390.1	7.377057103361290
Barnsbury	332	87	906.7	10.422839
Clerkenwell	628	144	1521.8	10.568353
Beacon Hill	478	106	2324.1	21.92545

Table 7.1 Cumulative axial revelation for case study areas.

to blue in the colour spectrum). So we would expect a low value of total axial revelation by length.

Brentham Garden Suburb

Finally Brentham Garden Suburb (see Fig. 7.5) was chosen as a companion to Hampstead Garden Suburb being built in roughly the same time span with similar motives and architectural theories, but at completely different scales. For more details on the particulars of each site see the later chapters which reported on the sites in more detail. Given the extremes that can be possible in an axial map it is hard to inspect the revelation values directly from the visualisation as for an area we find almost all the values are near the mid point (greenish) to blue (low).

Analysis

Table 7.1 below shows the cumulative axial length revelation values for the four case studies area. Looking at the cumulative revelation per unit number of axial lines we can see that the urban areas have similar values of near 10.5 while the suburban areas of Hampstead Garden Suburb and Brentham Garden Suburb have lower relation values suggesting that the suburban areas have less total change compared to the larger axial areas.

For comparison Beacon Hill, a vibrant central site in Boston, has been included. This area was mapped at a different metric scale but significantly has a far higher axial revelation than the London central areas. This value was presented to give an idea of how much the revelation per line ratio could change in the right conditions.

For the more comparable case study areas in London it does appear as if the axial revelation is exhibiting some of the small scale spatial structure which makes the urban and suburban areas distinctive and possessing of character.

Conclusion

So what has happened? There has been considerable previous work such as that of Kaplan and Kaplan linking behavioural outcomes with perceptions of visual qualities such as ‘mystery’. It was theorised that revelation was linked with this visual quality and that link was reinforced by the experiment outlines in the chapter on revelation. It has already been established that there is a correlation between isovist revelation and that of axial revelation. In the case of the four test cases the two neighbourhoods with higher axial revelation were inner city areas. The two neighbourhoods with lower axial revelation are in the suburban locations. This confirms the work of others that changes in isovist properties are not unrelated to our experience of the degree of interestingness of an environment. Rather, if it is a belief that space is unrelated to our perception of the character of an environment, then some counter argument must be presented to explain the evidence found.

We see that the contention that if space is divorced from place that of the revelation measure should not relate to any place. The work of this chapter is clearly inconsistent with that assertion.

Key Points

- Axial revelation is applied to the case study areas.
- The sum of axial revelation per line appears to separate urban and suburban spaces.
- While axial revelation is a low-resolution instrument it does provide more evidence that within a neighbourhood heterogeneity is related to the perception of the urbanity of a place.

Chapter 8: The Theory of Point Intelligibility and Point Synergy Mapping

Summary

This chapter returns to the first part of the place hypothesis that a place requires a region of spatial continuity to be identified as a continuous region. From the literature review it appears that both intelligibility and synergy are related to named regions. The foundations of intelligibility are described and one aspect that appears to be relevant is how intelligibility scales with graph size. The chapter introduces the notion of extrinsic (size-dependent) and intrinsic (inherent complexity of layout) intelligibility and demonstrates how they relate, then hypothesises the connection between the two. The chapter then goes on to introduce a number of intelligibility processes and introduces a local intelligibility process called point intelligibility. This local intelligibility gives a value of intelligibility for each node in the system. A visualisation mechanism is introduced for this and from this it is observed that what appears to be neighbourhoods of London are revealed. By using vicinity[1] rather than radius as the localising mechanism the clarity of the images is shown to be improved. The chapter then goes on to show that the effects are not a byproduct of the aggregation mechanism and that these effects are not an inherent outcome from axial mapping (that is, a random axial map does not show up neighbourhood regions). From this it is suggested that the regions of constant intelligibility and constant synergy are the results of occupation and emergent spatial processes rather than simply the results of the axial line mapping mechanism.

Place and neighbourhoods

It is the core of the place hypothesis that neighbourhoods and a feeling of place are rooted to a strong extent in the spatial configuration of the local physical environment. Neighbourhood is an interaction between a spatial locality and the people living within that locality: people identify regions, which leads them to create associations with those regions, sharing these regions ultimately creating meaning and so place. Sharing regions can take many forms but is apparent in the naming of the place (for example Dartmouth Park, Barnsbury). The hypothesis of this thesis is that a place requires two attributes. It is a defined, delimited area (it is spatially bounded) and has a discernible character (it is identifiably different from elsewhere, it is distinctive, memorable), so that local spatial changes, such as viewing point revelation, provide variations that aid in the cognition and orientation of an inhabitant (although there may be other analytic methods).

The basis for this section emerged from early space syntax research. A number of studies revealed that there was a generally high r squared correlation between the measure integration

1. The Vicinity relativisation methodology was introduced in chapter 4, Introduction to Space Syntax Theory.

(described in detail in Chapter 4) and human movement patterns of between .6 to .8 (eg: Hillier et al, 1993, 1987, 1983; Peponis et al, 1989; Read, 1999) and vehicular drivers (Penn et al, 1998a; 1998b). It was observed that the boundary chosen had an influence on the degree of correlation and that choosing a specific boundary could maximise the correlation (Hillier et al 1992). Hillier went on to suggest these maximised boundaries could be used to give a rigorous definition to a local urban area. Hillier then suggested that these could be considered as the 'natural' boundary of the area, and observed that these coincided with named areas in London.

Hillier was not alone in the field of space syntax in hypothesising a link between space, movement and a 'natural' boundary nor of taking the notion of 'natural' boundary (also known as sub-areas) further and proposing that the natural boundary could also be the foundations of the neighbourhood boundary.

Peponis choice method

One of the earliest syntactical approaches to finding 'natural boundaries' was Peponis (Peponis 1989). Peponis observed from a study of Greek towns that lines of high choice (see chapter 4 for a definition of choice) measure could be used to mark the boundaries of sub-areas. When examining an axial map of choice this method does appear persuasive but it also suggests that prime integrators (where there are many axial lines of high choice) are typical boundaries. Yet this method does not seem to be full proof. Kensington High Street in London, like many other high streets, is at the heart of the area rather than defining the periphery (boundary).

Read Mean Integration

Read (Read 1999, Read 2003, Read 2005) suggested that Dutch cities are an aggregate of large scale 'super grids' and local grids and went on to suggest that areas could be highlighted by finding concentrations of high integration radius 3 areas. The work presented is persuasive but no evidence is given to the goodness of fit with named regions. Also this work makes no claims as to generality above the Dutch settlement, so while this method may be more general, failure to do so beyond the Dutch urban design realm would not invalidate its contribution.

Raford and Hillier

Raford and Hillier also proposed using groups of similarly oriented axial lines to produce a 'directional analysis'. While these methods were not ostensibly designed to find neighbourhoods, they did appear to correspond to named regions consistent with neighbourhoods in Boston.

Embedded mean depth (EMD)

Embeddedness (EMD), created by Yang and Hillier (Yang & Hillier, 2007)[2] was principally developed for a segmental axial map. EMD measures the rate of change of the number of elements at a specific radius (number of steps from origin). While doing so it was observed that regions of continuous EMD appear to map against known regions in London and Boston. No results of stricter tests have been yet been

2. First published four years after the initiation of this PhD and contemporaneous with its published works.

published and this work also leaves open the meaning of its interpretation. What the work fails to provide is a convincing hypothesis concerning what is it about the rate of change of elements that appears to explain these neighbourhood-like regions appearing and how that hypothesis relates to known space syntax theory. This work is contemporaneous with this thesis so it is possible and likely that such an explanation will emerge in future work.

Metric Mean depth

Hillier (Hillier 2007) also introduced a method derived from the segmental model of space that calculated neighbourhoods based on the consistency of the metric mean depth from a segment within a metric radius. It has been stated by Hillier (Hillier, B., and S. Iida. 2005) that angular-based methods and segmental methods are more accurate in terms of predicting pedestrian movement. Mean Metric depth (MMD) method is similar to EMD but in this case uses metric distance and angle rather than element count as the basis for its regions. Again Hillier's work comments on the apparent consistency between MMD region maps and named regions in London but does not present any empirical work to confirm whether neighbourhood boundaries are being truly identified. Another omission of this work is a strong theoretical basis for how and why this work is identifying the named areas. Lack of such a theoretical frame work gives rise to the problem of some underlying mechanism which is giving rise to both EMD and MMD (or indeed all the methods previsouly mentioned).

Null method

For ease of reference it would also be useful to introduce the null method here. One problem with the work survey above was the absence of an assessment of how well the methods have performed against real world data. If we see a patch of constant value around a known area it is tempting to think that space is speaking about its occupation. Yet the question must be asked to what extent do any or all of these patches/regions/natural neighbourhoods occur randomly? Analytically it would be quite difficult to assess this but one method that is quite simple to perform is to produce a method which could be guaranteed not to be measuring anything and then assess how well that method performs against the others. If any method does as well as the random method we might well suspect that the method is doing no better than chance.

To this end a null (guaranteed useless) method was developed, the basis for this was to attempt to see how a completely random value, which was certain not to indicate the presence of neighbourhoods, would perform. The null value was computed by assigning a random number from 0.0 to 1.0 to each axial line and then following the same theoretical aggregation process (see Point Intelligibility below) as the other methods to produce the same number of clusters or neighbourhoods as they did. In theory, this random method would show the effects of the aggregation process described latter, which in itself will be partially sensitive to the structure of the network.

Graph theoretic measures

As mentioned in the introduction the methodology of this thesis relies strongly on the methods and theories of space syntax(Hillier). It can be observed at this point that the underlying operation of looking for regions from a syntactic derived graph (see chapter 4 for how the network/graph is extracted from the axial spatial representation) could be an implementation of an algorithm for the detection of community networks or clusters, see Newman (Clauset, Newman et al. 2004; Newman 2004)[3]. detection is an aspect of the study of complex systems that generally attempts to find communities in networks, typically in, but not restricted to, social networks. The utility of finding communities of related genes (Wilkinson and Huberman 2004) has spawned a considerable effort to find community-like structures in large graphs.

Pothen, Simon

Historically, the most popular is the spectral bisection described by Pothen (Pothen, Simon et al. 1990). This is based on the eigenvectors of the Laplacian matrix of an undirected graph. If the network separates into communities, there will be an eigenvector with an eigenvalue slightly greater than zero. Briefly, by tracking the eigenvectors back to the original graph, it is possible to approximately find the communities themselves. This method is simplest when looking for only two remote communities; by looking at the eigenvector of the second lowest eigenvalue it is possible to retrieve the respective communities. As pointed out by Newman (Newman 2004), this method is limited by necessity to finding the eigenvectors of an $n \times n$ matrix and can only split the graph into two very weakly connected components. Clearly in the case of the neighbourhood finding task, the neighbourhoods are strongly connected to the surrounding urban fabric and the spectral case would be unfit for this purpose.

Kernighan and Lin

The second method is attributed to Kernighan and Lin (Kernighan and Lin 1970). Their method assigns a cost to divisions of the network and then attempts to find the optimal division(s). The cost function measures the number of links within a given set minus the number that lies between it and another set. This algorithm may misclassify nodes if the number of nodes in each group is not known prior to the operation of the algorithm. As such it also suffers from the fact that the number of differing groups must be known in advance, something we cannot be sure of in the urban graph.

Scott

A third method described by Scott (Scott 2000) and used in social networks is known as hierarchical clustering. The idea is to create a measure based on the similarities between all pairs of nodes in the graph. There are a number of methods to define this 'distance.' Once measured, the values can be used to group pairs of nodes together. The process is then repeated, grouping the pairs together in pairs, and can be repeated until there are two or only one node in the graph. In some respects we can regard finding the point synergy and point intelligibility values as a way of finding the kind

3. Community in this case is a term derived from social network theory suggesting a group, clan, cluster, assembly or clique rather than a community in the neighbourhood sense.

of values suitable for hierarchical clustering. However, we can see from the point noise map and the fact that the point synergy and point intelligibility maps are not identical that the algorithm is not looking for the 'similarity' between pairs. If it did, the point noise map should operate in a similar manner to point intelligibility and point synergy, which it does not. As such it would be fallacious to regard the point intelligibility maps as an extension of hierarchical clustering. While the synergy and point intelligibility mapping produce a single value per graph node/axial line, for the hierarchal clustering method there is a value that represents the separation between each pair. As such, it is not possible to plot the 'separation' values back onto the axial map in the same manner as is done in the point synergy and point intelligibility methods.

Another commonly used sociological method is apparently similar to the point synergy and point intelligibility methods, in that it looks for the correlation between rows in the adjacency graph. This algorithm strongly depends on the social network phenomenon that in graphs of friendships and groups there is a tendency that if A knows B and B knows C, then in a cluster community, C will know A. As such, there will then be a strong correlation between the presence and absence of similar connections. For axial maps, it is known that it is the reverse of that which is found. For streets, if street A intersects street B and street C intersects street B, then it is highly unlikely that street A will intersect with street C. As such, the adjacency or correlation test is likely to fail. This property, which can also be seen as a weak clustering coefficient, is also the property that separates the class of Axial maps from the general class of small world graphs (Watts and Strogatz 1998). This method is also poorly suited for use in understanding spatial networks due to the size of the matrix that needs to be processed.

Girvan and Newman

A fifth set of methods depend on edge removal. Girvan and Newman (Girvan and Newman 2002) introduced an interesting process where links between nodes are removed until the groups are naturally separated into completely independent graphs. Girvan and Newman use edge betweenness (Freeman 1977; Freeman 1979), which might be called edge choice in the architectural community. The first edge e on graph G is found, which is on the largest number of paths from all points to all other paths. Then edge e is removed. If for example a graph was held together by one bridge, then the bridge would be the point that would hold the highest betweenness/choice value and, as such, cutting would be the best choice in separating the graph. This algorithm works reasonably well and has the advantage, like the point synergy measure, that it does not need to know the number of clusters in advance. One of the interesting findings of Lynch (Lynch 1960) is that boundaries can lie upon principal streets. For example, in London, Oxford Street is the intuitive northern boundary of Soho. An algorithm based on betweenness/choice would not use a main backbone as a boundary and as such be bound to Peponis-like high choice boundaries. In a later chapter, we will see that the point intelligibility measure does not suffer from this effect.

An extension of the edge removal method has been implemented by Radicchi (Radicchi, Castellano et al. 2004). This assumes that short loops are likely to represent a closely knit community. Radicchi used an edge clustering coefficient to measure the candidate most likely to separate the networks. As mentioned previously, in axial maps there is a weak clustering coefficient and, while this is an excellent algorithm, it does appear to be specialised at looking at social networks with high clustering coefficients.

A final approach was proposed by Wu and Huberman (Wu and Huberman 2004). This algorithm considers the graph as an electrical circuit and considers the potential when applying a voltage between two randomly chosen vertices. If the network divides into two, then there should be a large change along the border between them. While very efficient, this algorithm assumes that there are 2 or N groups into which the network must be divided, and also suffers from the fact that a strong connection can be a barrier problem, just as with the Girvan and Newman approach.

In summary most of the core computing approaches to community finding appear to expect to know the number of neighbourhoods in advance and typically expect the kinds of small world graphs common to social networks but not axial map. As such these methods are not appropriate to the task of neighbourhood finding in urban axial maps.

A new approach to 'natural boundaries' via intelligibility and synergy

The syntactical basis for this section emerged from early space syntax research. As mentioned a number of studies in axial mapping of neighbourhoods revealed that there was a generally high r squared correlation between the measure integration and human movement patterns. It was observed that the boundary chosen had an influence on the degree of correlation and that choosing a specific boundary could maximise the correlation (Hillier et al 1992). Hillier went on to suggest these maximised boundaries could be used to give a rigorous definition to a local urban area. Hillier then suggested that these could be considered as the 'natural' boundary of the area, and observed that these coincided with named areas in London. The degree of correlation between movement and integration also declined sharply in certain pathological cases such as dysfunctional housing estates Hillier (Hillier et al 1992) observed in these cases that the degree of intelligibility of the area also declined.

Are these 'natural boundary' areas representing some notion of our personal understanding of neighbourhood? One argument against the Hillier-derived view of natural boundaries is that neighbourhoods which were used as the 'named areas of London' are quite vaguely defined entities existing in an *a priori* form. While there might be agreement over the centre of an area (Barnsbury or Camden) (this might appear roughly on the Ordnance Survey Map), it could be said that many non-overlapping boundaries could meet this test. For a better test one should look for a correspondence to geographic boundary of the neighbourhood as it is experienced. There are many sources for geographic 'bounds' but many of these might be distorted for administrative or commercial purposes, for example the estate agent's map of highly desirable value houses in Islington

$$I_g = \frac{\mathbf{I}^{\infty} \bullet \mathbf{C}}{\left(\left\|\mathbf{I}^{\infty}\right\|\left\|\mathbf{C}\right\|\right)}$$

Equation 8.1 Definition of Intelligibility

Where Ig is the intelligibility for a set of points such as a g, vector I is the vector computed range of integration at infinity values and C is the corresponding vector of connectivity or degree for each node in the graph. This assumes that the graph has more than two values.

might be much larger than that which the inhabitants might think of.

It might be argued that if any property emerges from a neighbourhood, then the manual definition of neighbourhood creates a 'circular' argument of some sort where inputs are blended with outputs. It has also been reported by Read 'While this feature is not absent in Dutch cities, research has shown it to be less reliably characteristic of Dutch urban layouts, and of the relationship between the local and the whole-city spatial and activity scales in Dutch cities' (Read, 1997). Currently, it is unclear whether this lack of reliability is due to the choice of neighbourhood boundaries, for example Dutch authorities might well be adjusting the natural neighborhood boundaries to give each neighborhood an equal number of inhabitants. The alternative to using clearly defined official neighbourhood boundaries might well be having researchers define the neighbourhoods themselves. If this were the case, the bias removed by exercising the external modification of boundaries would be replaced by the absence of surety that boundaries had not been modified to match the results.

In *Space is the Machine*, Hillier (Hillier 1996) identifies well formed neighbourhoods as having specific configurational properties, and as such it could be argued that the structure of space influences the character of a neighbourhood beyond simply guiding movement patterns. The two properties of intelligibility and synergy are mentioned in the book. Hillier's definition of intelligibility takes two forms. The first is purely mathematical. If we begin with a known area that has been encoded as an axial map and the structural values of integration and connectivity are taken for the subset of lines that lie within or intersect a geographically limited named area, then it is possible to find the correlation or normalised dot product between all the value pairs. This correlation coefficient can be regarded as the intelligibility value for the selected subset. The observation by Hillier is that this value can also be regarded as an apparent measure of the degree of maze-likeness of a space, with low values indicating an area that is difficult to navigate and high values (near one) indicating an area that is easier to navigate.

We may understand the mathematical definition of intelligibly to be slightly more refined than the Hillier definition. We might consider the concept of correlation to be a statistical test against data, rather than the purely mathematical measure of the structure of a system represented by intelligibility. It might be clearer and more mathematically formal to think of the mathematical definition of intelligibility as the cosine of the angle between the two vectors of integration and connectivity, once the values have been centred on their respective averages. While the use of the dot product might appear artificial, it does clear the way to a greater understanding of the concept of intelligibility and remove any confusion that might arise regarding the purpose and operation of intelligibility. In other words, intelligibility is

	Intel	Synergy	Size
Amsterdam	0.0971	0.3349	9776
Barcelona	0.1703	0.6826	5575
Bham	0.2059	0.4188	2374
Denver	0.376	0.906	2092
Einhovan	0.1082	0.3428	5782
Kings cross	0.2744	0.4625	1124
Dhaka	0.1423	0.273	1566
Hong Kong	0.1741	0.3804	916
Kings Cross	0.2744	0.4625	1124
Leicster	0.1433	0.4543	5180
London4	0.0874	0.2758	4472
Modern Kersman	0.1094	0.5253	1870
Modern Hamedan	0.1219	0.4064	3855
Modern Qazvin	0.0891	0.2869	3723
New Orleans	0.2048	0.5651	4846
Norwich	0.1638	0.2696	2119
Nottingham	0.09	0.3021	4365
Winchester	0.1289	0.3838	616
York	0.1141	0.1955	1773
Carlisle	0.1683	0.2839	1254
Soho (London)	0.6474	0.7485	78
Oxford	0.1125	0.1917	1622
Atlanta Central	0.6319	0.7488	150

Table 8.1 Sample of intelligibility compared to size for sample cities.

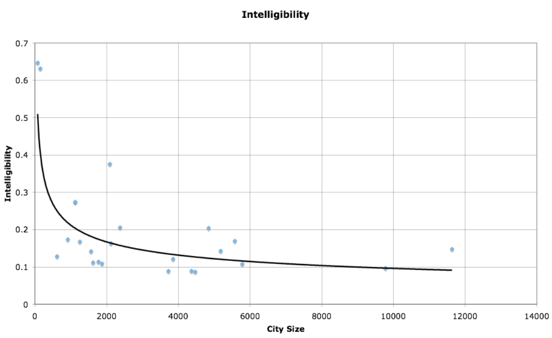


Figure 8.1 Plot of intelligibility against city size.

a ‘purely’ mathematical construct that is presented without a statistical property that has any linkage to dependant and independent variables. We can understand intelligibility as a structural measurement in a pure graph/network without any linkage to navigation. For this thesis the mathematical definition of intelligibility will be used - see Equation 8.1.

One property that is not discussed in Space is the Machine is the normalisation or comparability of intelligibility values. One of the problems with the definition of intelligibility given by Hillier is that it gives the appearance that a larger system will be less intelligible. This could be saying two things. The larger a system is, the more likely it is that the system is harder to navigate. Consider the case of a taxi driver who has moved to a new city. The smaller the city, the fewer places the driver has to become familiar with, and so the simpler the city is to learn the more intelligible it is. So on one hand, the size of the system has some effect on the navigational task. At one extreme would be learning to move around a single floor open plan office. If you always see your destination and your route, this would be a simple navigational task. In fact it is so simple that we might not even think of it as navigation. So in one interpretation, size matters and larger systems should be more unintelligible. We might think of this as the extrinsic intelligibility of the configuration of a system.

Given that intelligibility by Hillier is defined as a correlation coefficient, the other item we might need to consider is that high intelligibility in small systems is a property of the process of finding the correlation coefficient. To avoid this, we begin by using the adjusted R squared values for all correlation measurements; yet experiment shows that if we make this statistical allowance, then the R squared value still appears to not change with the size of the system.

On the other hand, it is possible to make a spatial network that is difficult to navigate despite being relatively small. Consider a maze; a maze is deliberately designed to make the task of navigation as complex as possible. As such, the properties of the maze must create a space that is less navigable for its (axial) size. In this case, the configuration of the maze must be the primary consideration. We might think of this as the intrinsic intelligibility of the system, an intelligibility that is not dependent on size but strictly on the configuration.

It would appear that the Hillier notion of intelligibility fuses both effects together. It may measure the effects of both size and configuration. Clearly the Hillier view already picks up some elements of space. For example, the more broken space of a maze would give a higher density of axial lines per square meter, which would give a lower value of intelligibility. This leads to the question - is it possible to separate out the effects of size and configuration on intelligibility?

Multi Sample Intelligibility

One method is to find the intelligibility for a number of cities, such as those listed overleaf.

One observation that should be made from compiling the data is that for large systems a single high connectivity point is likely to disturb the general pattern of the correlation. From this point of view, it is better to correlate the log of connectivity against integration. This goes against the original Hillier definition of intelligibility and is only useful for very large (greater than 1,000 lines) systems. So while this 'compressed' intelligibility, as it is known, is used by others in the field, for the sake of clarity it is not used in this thesis.

dimension	intelligibility
6	0.897652924
7	0.891731224
8	0.896944302
9	0.933602579
10	0.916922918
11	0.907765281
12	0.908381361
13	0.932245636
14	0.931899311
15	0.871196549
151	0.573562253
152	0.572786556
153	0.576887206
154	0.580516765
155	0.582848288
156	0.567666402
157	0.567446406
310	0.453691515
311	0.454948889
312	0.456755928
313	0.456489149
314	0.456597448
900	0.285435471
901	0.285758668
902	0.285423022
903	0.284294688
904	0.2848207
905	0.284449579
1655	0.214529105
1656	0.214856135
1657	0.215211956
1658	0.21523506
1659	0.215568326
1660	0.215568707

Table 8.2 Computed intelligibility for given size (dimension)

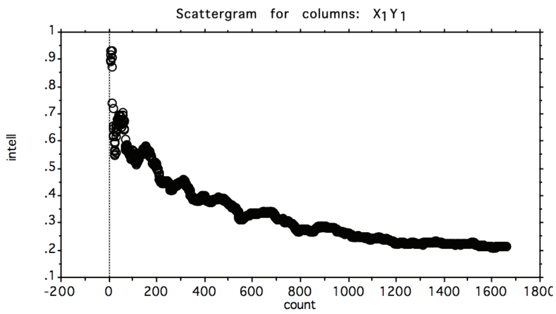


Figure 8.2 Intelligibility - dimension curve plot for Barnsbury

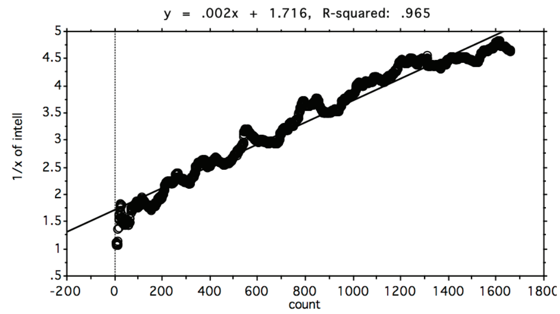


Figure 8.3 Reciprocal of intelligibility against system size (count) Barnsbury 4

Plotting this data (see Figure 8.1), we recognise that the cities are approximately following a reciprocal curve. This plot is generally very weak, as we are seeing the effects of both extrinsic (size) intelligibility and intrinsic (configuration based) intelligibility. If we look at the correlation between size and intelligibility, we find that there is an R squared correlation of 0.521 with the value of size raised to the power of ~1/3. This suggests two things: first, that the change in size (extrinsic intelligibility) can only explain half the variation in intelligibility. Second, that the change in intelligibility drops by approximately the third root of the size, suggesting that while bigger systems become more unintelligible they do so at a steadily declining rate.

Clearly, it would be informative to be able to change the size of the city while retaining the same general level of intrinsic intelligibility. This would allow a better view of how intelligibility changes with size when the configurational measure of intelligibility is the same.

Intelligibility dimension curve or intelligibility profile

One method would be to look at a particular configuration that we believe to have a consistent intelligibility across a number of scales. For the basis of this experiment we begin with a map of Barnsbury4 (Figure 8.2). It would be reasonable to assume that the local intelligibility of the space would remain roughly constant over the urban region of the map. We can help eliminate this local change in intelligibility by processing a number of cities separately and comparing the results for consistency. If the local constancy assumption is maintained,

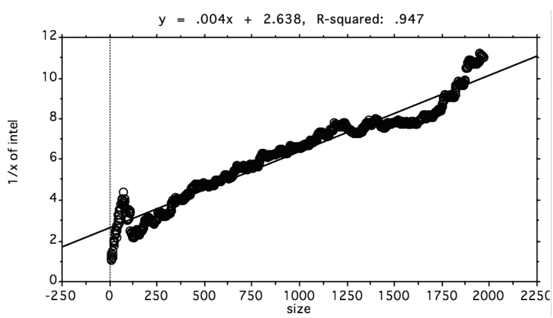


Figure 8.4 Plot for old Shiraz, 1800

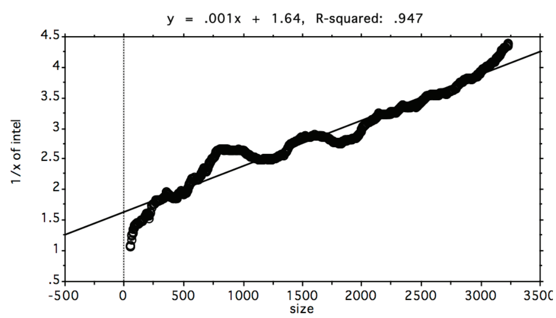


Figure 8.5 Growth curve for Peach Tree Street, Atlanta, USA.

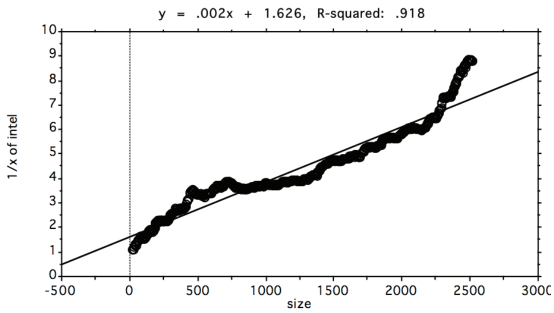


Figure 8.6 Growth curve for Belgrade.

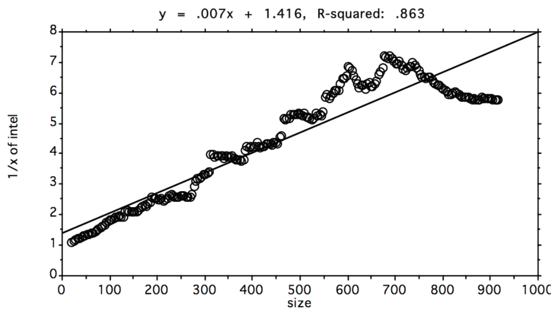


Figure 8.7 Growth curve for Hong Kong.

then it would be possible to view how the intelligibility of an urban system changes as it grows.

One way to do this is to take the axial map of Barnsbury. We begin by selecting one random starting point near the centre of the map. From this point we build a tree that is the minimum spanning tree from that starting point. This tree can then be ordered into a list called the source list. This creates an ordered list where each sequence from the beginning is guaranteed to form a single continuous network. Or, we can say at each point that if we add the next element of the source list to a graph, then the graph will be connected. Any method that exhibits this property can be used to generate the source list.

The intelligibility-dimension table can be found as follows. Take the list and add the first five elements to a set of axial lines. The ordered property of the list guarantees that this will form a continuous network that is a sub-graph of the source map. Process this network to produce the normal measures of global integration and connectivity. Use these per line properties to compute the intelligibility of this sub-graph. Thus, we have the intelligibility factor for a sub-graph of size/dimension N where N = 5. Next add the N+1 element of the source list to the sub-graph and reprocess the N+1 intelligibility value. Repeat this process until all the elements of the source list have been appended. A sample of an intelligibility-dimension table can be seen in table 8.2.intelligibility

Plotting this data gives Figure 8.2.

In Figure 8.2 we see a simple plot of the intelligibility-dimension table for Barnsbury. This view confirms our suspicions. From the table and the Figure 8.2 we can see that the table begins with a very high (near 1.0) intelligibility factor. As new axial elements are added to the sub-graph, the intelligibility factor quickly drops, then rises. When the system is small, the effects of one outlier on the intelligibility factor can be quite considerable. As the system grows, the individual effects would diminish. As we can see from the final tail of the plot, the variation in intelligibility at the larger system sizes is minor.

Upon examination, there does appear to be a clear curve in this plot. Naturally, this cannot be a complete reciprocal curve in that the intelligibility factor can never be larger than 1.0 (or less than 0.0) and the value of N, the number of items of the sub-set, cannot be less than 2. As an approximation, it appears that the reciprocal of intelligibility grows linearly with the size of the system. If we re-plot the values, we find Figure 8.3.

This curve appears to be a straight line with an R-Squared value of 0.965. This type of line appears no matter which central axial line we choose as our starting point. We can reproduce this experiment using either the same urban structure from different points or different urban maps (see Figure 8.4, 8.5, 8.6 and 8.7).

Intelligibility profile

From this work it appears that from an empirical point of view the reciprocal of intelligibility grows linearly with the size of the system, but with different gradients. This intelligibility growth profile is hypothesised to be a single measure over a number of urban systems. While the slope of the curve changes from axial map to axial map, the existence of a 'core' linear feature strongly suggests the existence of an intrinsic intelligibility. Around this general size dependent change in intelligibility we see variations that can be possibly rationalised as effects of the change in local configuration. For example, a city might begin as an unintelligible mix of spaces, such as the historic walled area of Barcelona, and then grow and change in configuration by evolving into a large complex grid, as in Barcelona. This would be seen as a change in the slope of the line, as seen, for example, in Hong Kong (see Figure 8.7, Growth curve for Hong Kong).

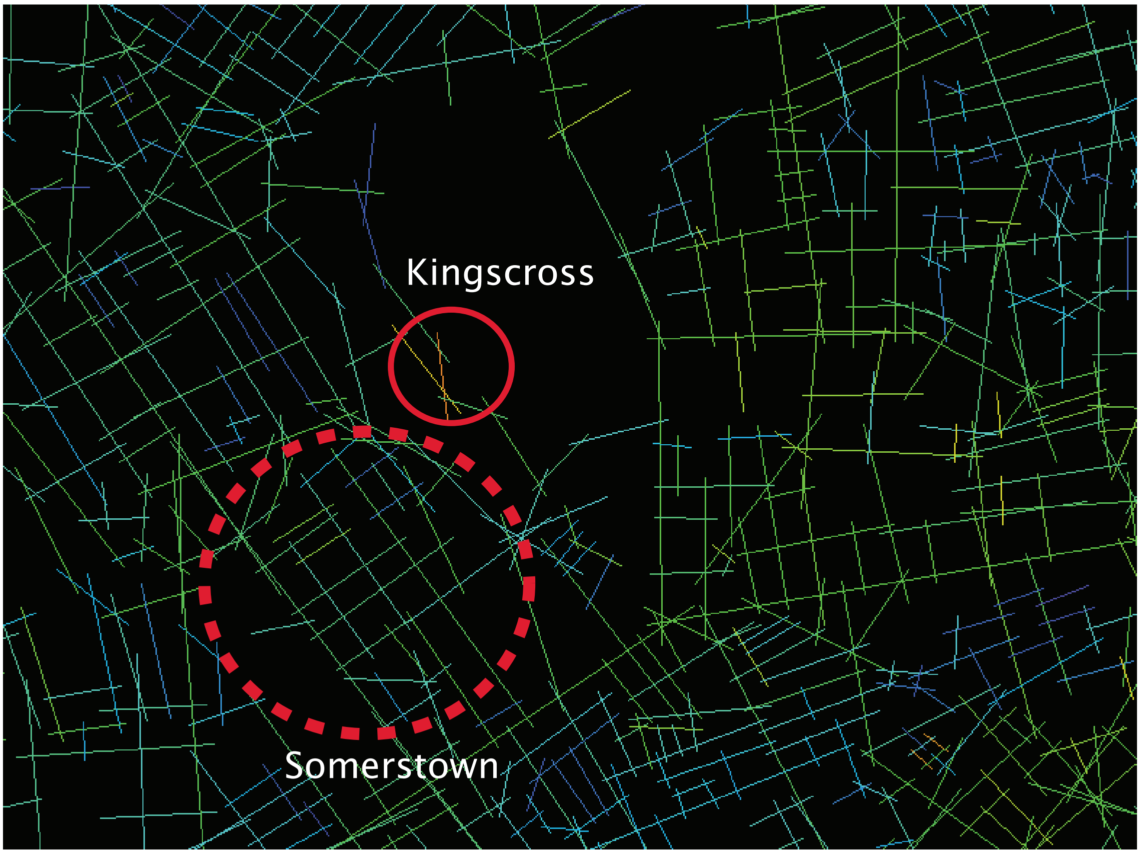


Figure 8.8 Plot of point intelligibility for the King's Cross area - problem line in circle.

What is remarkable is that the reciprocal of intelligibility is generally consistent across the urban scales of the intelligibility growth profile, as suggested by the high correlation factors (r squared near 0.9 for 4 cases). This suggests that the innate complexity (intrinsic intelligibility) of an urban system remains remarkably constant, while the size dependent intelligibility declines as the system grows. It is interesting to observe that different cities have differing values of correlation slope, which will now be used as the definition of the value of the Intelligibility Profile (Iψ). If we look at the value of the Intelligibility Profile (Iψ), we will soon notice that a fairly navigable area, like Barnsbury, has a value of 1.76, while an Islamic and fairly complex area, like Shiraz, has a value of 2.68. We might therefore conclude that the Intelligibility Profile (Iψ) is a scale-free measurement of the intrinsic intelligibility of an area, free of extrinsic (size) contributions.

This gives an indication of how we might proceed to understand how intelligibility changes with the size of the system for a constant level of intrinsic intelligibility.

Where I is a (near) constant representing the intrinsic intelligibility, or the scale free intelligibility, I_n represents the intelligibility of a system of size n. While the size of the system is given by n, p is the measure of extrinsic intelligibility and is a power near ½, for example is 1/(2.857) for Barnsbury 4. Notice that this is near the third root power we found by looking at the general population of urban environments.

$$I = I_n n^{\rho}$$

Equation 8.2 Definition of scale-free intelligibility.

Equation 8.2 outlines our dilemma; we have two parameters that must be specified to let the intelligibility of a system of size n be comparable to the intelligibility of a second system of size m. If we assume the system is identical in intrinsic and extrinsic intelligibility, we can then make a reasonable prediction of how intelligible or unintelligible a system may become when it grows (or shrinks) to a system of size m. Without two out of the three values (intrinsic intelligibility, extrinsic intelligibility, and the size of the system n) we are operating blindly.

The concept of intelligibility is remarkable, but must be regarded as any singular dimension in the understanding of an urban environment as an oversimplification of the rich complexities of reality. For example, if we take a strict N by M grid of axial lines (where N ≠ M), then the intelligibility value will equal one.

The proof is simple and non-mathematical. If we have N vertical lines and M horizontal lines, then all the horizontal lines must have a connectivity of N and the vertical lines must have a connectivity of M. The total depth for all the horizontal lines must be N + 2*(M-1), the total depth for all the vertical lines must be M + 2*(N-1). Integration is a function of total depth and N+M; there are only two values for total depth, hence there will be only two values for integration. We have seen that there are only two values for connectivity, so there will only be two points on the scattergram. Intuitively it is obvious that a scattergram of two points will have no deviant points and so the correlation must be one. Clearly the significance (p value) of the correlation will indicate a statistical problem, but significance is not part of the definition of intelligibility.

The maximum intelligibility value for a simple grid matches the perception of a perfect grid as being the most regular and orderly in opposition to the confusion of more organic layouts erly. The use of a grid as a logical layout has a long and diverse history, including the Indus Valley Civilization, the workers' village at Giza, Egypt, the Babylonian rebuilding by Hammurabi in the 17th Century BC, the Ancient Greek city of Mileus, and the standard Roman plan for military camps. It has informed ideal urban planning since the Wren Reconstruction plan of 1666 (Hanson 1989). One of the most notable uses of the nearly ideal grid is in the early planning of most US cities, most significantly Manhattan, which was created by the commissioners' plan of 1811 (Jackson and Dunbar 2002)..

Practice dictates that no truly grid-like city has ever been built, or indeed could be built. For example, a pure grid assumes that the city has no external connections (no roads leading into or out of the settlement) or other connections, such as the diagonal Broadway in New York, or blockages, such as Central Park in New York. So the grid-like city must remain an ideal.

At the other end of the spectrum, it would be unclear what ideal configuration would achieve the ideal of zero intelligibility, but it would be highly labyrinthine. Most importantly, we have discovered that we must be careful when comparing the intelligibility values of systems with different sizes, but conversely if two settlements are the same size, we can consider a comparison of these values a comparison of the intrinsic (scale free) measure of the configuration.

Point Intelligibility

The point intelligibility dimension curve has shown some interesting findings but it raises the question of which axial line (or graph node) to select as the starting point, does the selection point matter? Given Hillier's previous work on 'natural boundaries' does the correlation or curve change from starting point to starting point and if so then how?

Along with the choice of starting point, the question also arises that people don't know every street in their city but selected neighbourhoods of it. From chapter 4 it was seen that limiting groups of axial lines to a radius of the starting point can bring strong effects between the global and the local to light. Following this process through fully it is possible to envisage an algorithm which would use the correlation between connectivity and integration measures in a more local way. Given knowledge of space syntax methodology it is simple to envisage an algorithm which might give a value per starting point (per axial line) and within a radius.

Begin by randomly choosing a starting node (the point) and then find a local sub-graph by selecting all the lines that lie within three steps (three changes of direction) from that starting point. This sub-set we will call the locality set around a starting axial line/node. This selection process is analogous to finding the integration within a fixed radius. By finding the local correlation for this sub-graph, we determine a value (r squared) between 0.0 and 1.0, where 1.0 reflects a perfect correlation (ether positive or negative) between the integration and connectivity (degree) for each selection node, and a value of 0.0 indicates no (or a random) correlation. This value can then be attributed as a property to the axial line/node in question. When specifying point intelligibility, we need to include the radius to reach from the node. With an angular system, we could also specify the distance in degrees of change of direction about which we wish the immediate area to extend. For clarity pseudocode for the algorithm for point intelligibility by radius is given below.

Find the global integration and connectivity values as is usual for space syntax.

For each axial line A:

Find all connected lines which are less than N (for example 3) steps from A to form set S

For set S find the correlation c between the integration and connectivity for the elements of S.

Assign c as a measure of local measure "point intelligibility" to A.

As is common practice in space syntax, these values are visualised back on to the axial graph, using the value as colour spectrum from red (through orange, yellow, green) to blue representing the maximum and minimum values. Fig. 8.8 shows a sub-area of an axial map of London (London Mid 4) that has been processed to assign a value of intelligibility to each point.

This gives a value called the point intelligibility for a node. This process can then be repeated exhaustively using each axial line/node in a system as a starting point. Surprisingly, we can see that the area of Somers Town shown in the lines within the dotted circle appear to have fairly constant values of point intelligibility for each line (they have roughly the same colour). The map is not perfect, we can also see that there are axial lines, such as the back streets of Kings cross, that have very high values of point intelligibility. Examining the values of these locally highly integrated lines shows that there is a problem created by the existence of a highly segregated node with a small (order 3 or 4) subset within three steps. So the set S of lines within three steps is very small. For example if one has two nodes it is trivial to get a perfect correlation, with three nodes in an axial graph it is very easy to get high correlation factor. Statistically speaking in these cases, there is a very high correlation but with a low significance factor. Remember in the intelligibly growth curve the curve began with a minimum of 5 elements something which is not possible with highly segregated points. The instance of using a subset within three steps is not the only case where a small subset might create artifacts due to the size of the subset. For example, if we select axial lines up to an arbitrary metric distance, or up to an arbitrary radial (crow flies) distance, then it is possible for these problems to reoccur. Just as importantly we have seen that the intrinsic intelligibly declines with the size of the system in a predictable way creating a coherent bias or variability to the point intelligibility values.

To help eliminate this variability, there are a number of solutions. One crude solution is to eliminate all spaces that fail to have a minimum number of nodes. This eliminates the problem of unrepresentative size, but does nothing to tackle cases where the set is much larger than normal. An alternative is to implement the 'vicinity' method described by Dalton (Dalton 2005).

The concept of vicinity was originally created to deal with the problem of general relativisation of a sub-graph when trying to create a

Figure 8.9 Fragment of point intelligibility map for London, vicinity = 90

system of relativisation that could be applied to both topological integration and axial angular integration systems. The author's proposal was that instead of trying to normalise the total depth of a locality set for the number of lines, it might be simpler to fix the size of the set to some shared value. By removing the variability in size of the locality set, the necessity to relativise between lines in the same network is removed.

While admitting that this is not a complete or a perfect solution, Dalton suggests that this value might be sufficient to permit cross comparisons and allow the testing of new relativisation methods in angular systems while mathematically more complex processes using radius where developed. To implement the vicinity value for topological values, it is necessary to sort the depth values in order. For a system of vicinity 10, the first (smallest) 10 depth values are chosen. If we consider a small system where the step (or angular/metric) depths from a starting axial line have been computed, we can begin with a sorted list of node step depths D as

D = < 0,1,1,1,1,2,2,2,2,2,2,2,3,3,3,3,3,3,3,3,3,4,4,4,4,4,4,4,4 >

We can see the radius 3 locality as

R3 = < 0,1,1,1,1,2,2,2,2,2,2,2,3,3,3,3,3,3,3,3,3>

The vicinity 10 set would be

V10 = < 0,1,1,1,1,2,2,2,2,2>

More descriptively, the total depth for radius r is

$$TD_r = \sum_{i=0}^{i=N} d_i \{ d_i < r, 0 \}$$

Equation 8.3

Where d_i is the depth to node/axial line i from the starting node.

The total depth for a vicinity of V is

$$TD_v = \sum_{i=0}^{i=v} d_i \left(d_i \in \breve{V}, 0 \right)$$

Equation 8.4

Where d_i is the *i*th element of **V** and where **V** is the ordered set of depths from the starting node and the order is that of the distance from the starting node.

One common confusion arises from the often-made observation that in the above case there are 7 axial lines/nodes with depth 2 and in the vicinity case only 5 are chosen. Surely the choice of node is arbitrary? It should be obvious in the above depth-based example that the choice of the radius 2 node is arbitrary but the contribution to the total depth for any node at radius 2 is identical. That is, all orders of 5 axial lines/nodes at depth 2 from the 7 choices will always contribute a total depth of 10 (2*5=10), for any and all combinations of axial lines/nodes. It should also be observed that the same system can be used to create a locality subset for axial lines/nodes ordered by degree of angular depth from the start. From experiments in this case it has been found that for a case of 89 axial maps covering a number of urban systems, a value of Vicinity = 90

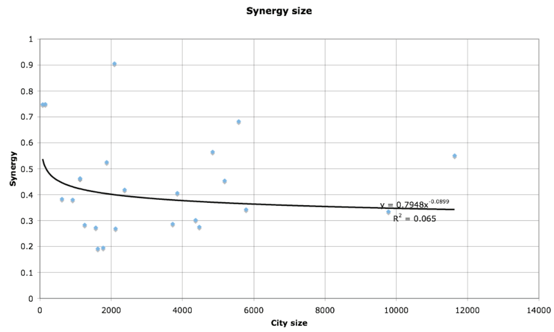


Figure 8.10 Plot of level of synergy against size.

correlated well with the value of integration radius 3. For the situation of point intelligibility mapping, the nodes are sorted by step depth distance[4] from the starting node, the connectivity measure, and then the integration value. This second sorting mechanism is not perfect but produces a reproducible result. Further developments may include taking samples at intervals to get a fair distribution of integration and connectivity values when step depths are identical. Alternatively, it might be preferable to use the angular depth from a point that would be more likely to produce the need to use any other data separate from depth in the vicinity formulation. The pseudocode now becomes

> Find the global integration and connectivity values as is usual for space syntax.
>
> For each axial line A:
>
> Sort all lines by step distance from A.
>
> Select the K (for example K=90) closest lines to A to form set S .
>
> For set S find the correlation c between the integration and connectivity for the elements of S.
>
> Assign c as a measure of local measure "point intelligibility" to A.

We can use the vicinity concept to capture a subset of axial lines/nodes around a selected

4. While not explored an angular depth value could be used as well.

starting node. If we consider nodes sorted by topological depth, we can create a correlation coefficient that will be comparable and, from a statistical point of view, will always be valid. If we plot the same axial map by point intelligibility we can see that these values, and therefore colours, are consistent and do not have the stark points of erroneous red (high intelligibility) found in the radius case. Notice that this introduces a value for vicinity that can be used as a parameter for the point intelligibility measure. Observe that when V = N (the size of graph) then every axial line/node will have the same intelligibility value, which will be that of the system.

In the original vicinity case Dalton was working with angle based depths from a starting node which typically produced a natural sorting pattern due to the fractional nature of the angular depths getting a set like (0.0, 0.0001, 0.011, 0.012, 0.3321). For the step depth case one gets a group of numbers such as (0, 1,1,1,1,2,2,2,2,2,3,3,3,3,3,3) taking the V = 11 case one gets (0, 1,1,1,1,2,2,2,2,2,3) and one is left with the question what do you do with the contribution of lines in the last vicinity tier? i.e where some are left of the vicinity set. In the original case of Dalton's attempt at angular depth the choice of which element in the last tier is irrelevant. If we label the set as (a0,b1,c1,d1,e1,f2,g2,h2, i2,j2,k2,l3,m3,n3,o3,p3) Dalton argued that the identity of the final element was irrelevant to the sum (a0,b1,c1,d1,e1,f2,g2,h2, i2,j2,k2,**l3**) adds to the same total depth as (a0,b1,c1,d1,e1,f2,g2,h2, i2,j2,k2,**n3**) and a0,b1,c1,d1,e1,f2,g2,h2, i2,j2,k2,p3). The contribution of the other values (m3,n3,o3,p3) was as irrelevant to the fair

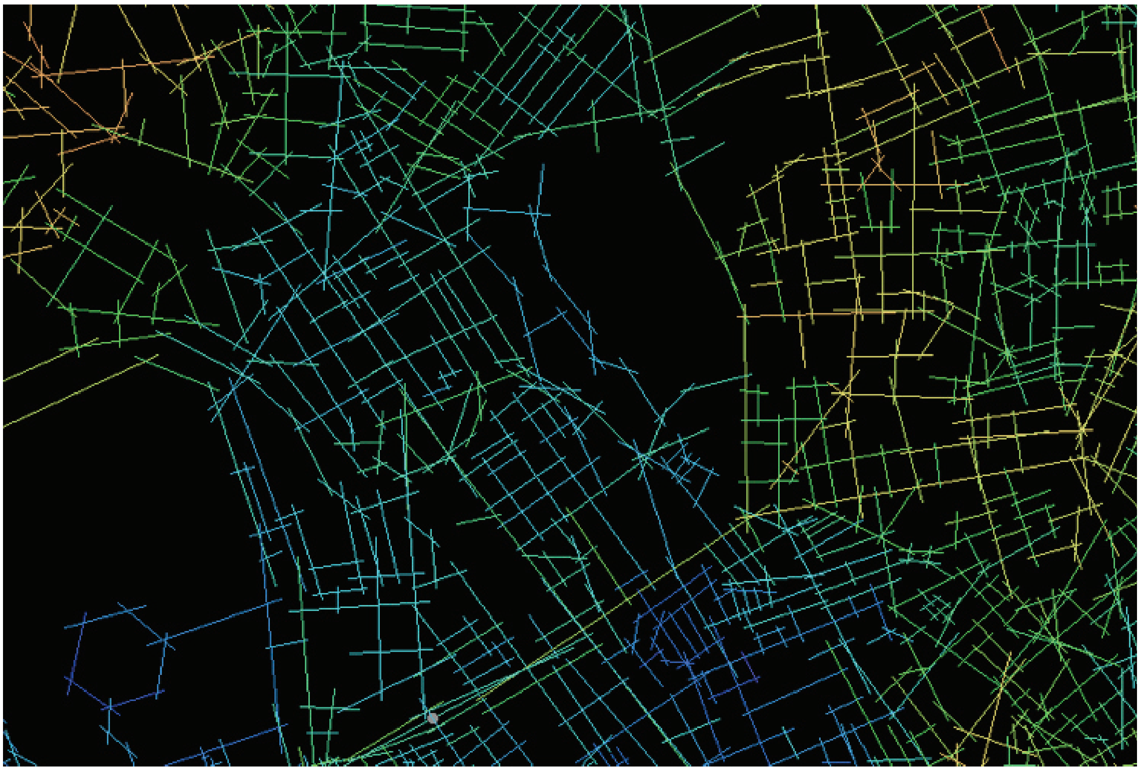


Figure 8.11 Fragment of Point Synergy map for London vicinity = 90.

Figure 8.12 Axial map of larger Barnsbury area coloured by Point Synergy V=180 R=4 with approximate regions in white.

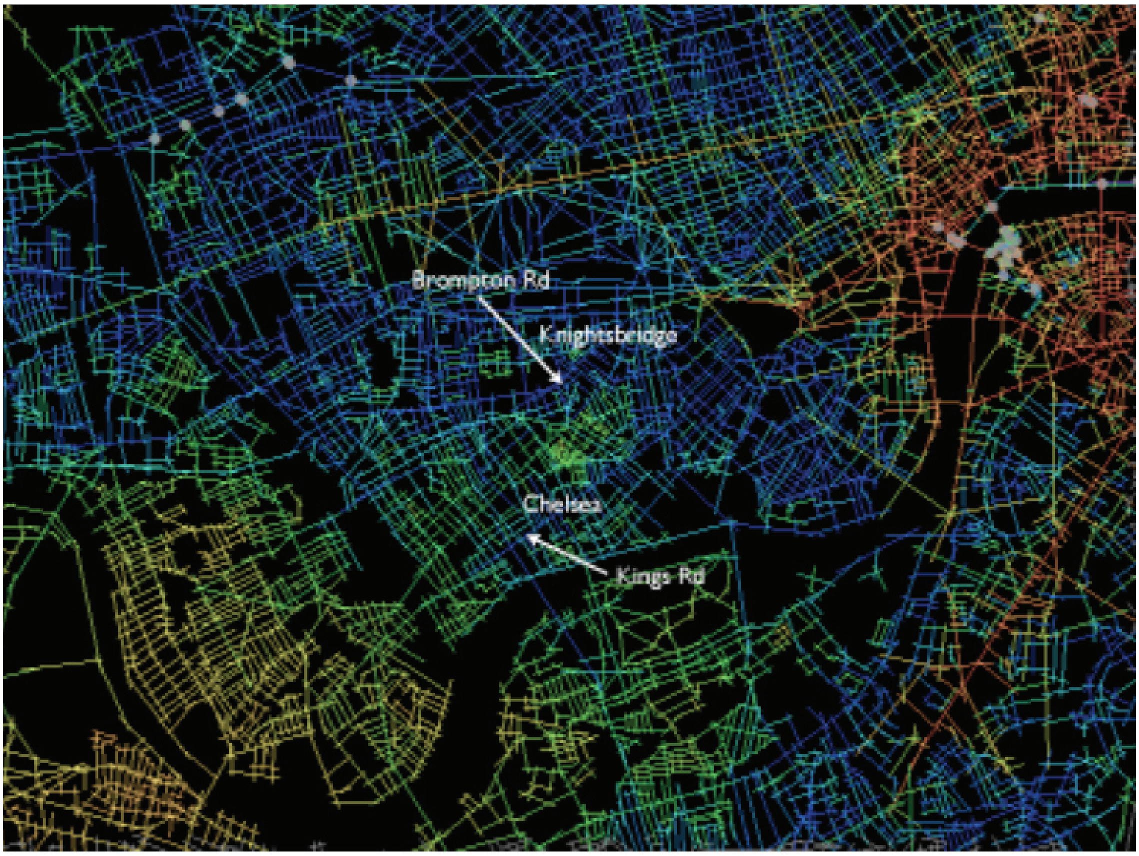


Figure 8.13 West End of London by Synergy R=4 V=90.

comparison of depth as the values beyond 3 in the radius case.

In the case of point intelligibility a reproducibility problem does emerge. In this case we have pairs of values of connectivity and global integration (a=(0,1.22), b=(1, 0.99),c=(1 0.89) … p=(3,0.22)). If we sort by step depth the integration values will be in some random order according to the sort value. Hence in this case the choice of elements on the last tier will have an effect. Thus if the values are recalculated the point values may change by small amounts. To compensate for this it is possible produce a secondary sort based on the integration values, that is the values are sorted by step depth first then when step depths are equal (such as elements b and c) they are sorted in the list according to the integration value. This method while stable and reproducible does produce a standing bias to low global integration values. Thus the best possible algorithm would sort by step depth from source and global integration then find the j values from the final tier and then pick j elements spread over the integration range of the final tier. In practice for large V (v > 20) this does not change the point intelligibility values by a huge degree but it can in certain cases be noticeable and is important for a reproducible result.

Applying this new vicinity based algorithm again to the same axial map we can see from Figure 8.9 that the occasional, highly variable value of radius based point intelligibility has been eliminated, giving better definition to the neighbourhood areas. We have also eliminated another potential criticism that could

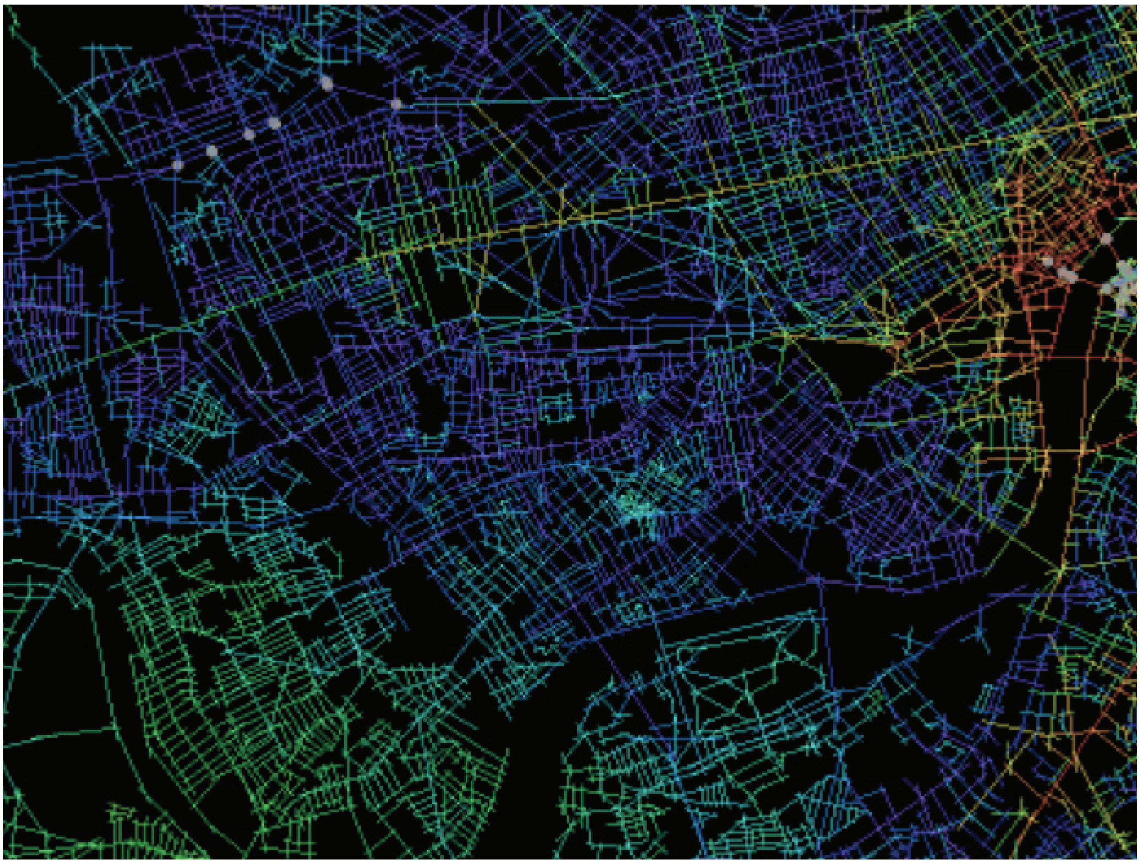


Figure 8.14 Axial map of the West End of London by synergy V=180 R=4.

have been levelled at this method. It is known that the intelligibility of a system is partly dependent upon the size of the system; generally the larger the system the lower the likely intelligibility, even when allowing for the size of the system in the correlation coefficient. By using Vicinity, the number of nearby nodes is kept constant, and so all the correlation coefficients are directly comparable.

For the rest of this thesis we will define point intelligibility with vicinity v, as the measure generated when a local area selected by the above vicinity method is used to compute the adjusted correlation coefficient between global Integration (Hillier 1987) and connectivity (or degree) of the axial map.

Synergy

The concept of Synergy is similar in many ways to that of intelligibility. Mathematically, synergy is the coefficient for the correlation between radius 3 and radius infinity. Hillier asserts that this is also a measure of the relationship between the local structure of the grid and the global structure of the grid. One could regard this as asking to what extent the local movement structure reflects the global movement structure of the larger scale urban fabric. Hillier goes on to make two observations. First, for well-defined neighbourhoods the local correlation vector tends to cross that of the overall urban environment. Second, the correlation coefficient tends to be strong (closer to one) for well-defined named areas

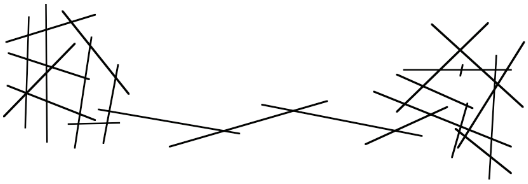


Figure 8.15 Sample system where likelihood of autocorrelation is high.

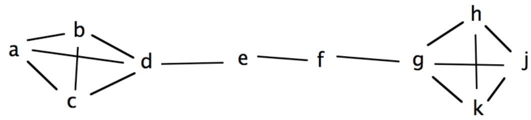


Figure 8.16 Dumbbell as a simple network.

and poor (closer to zero) for randomly picked non-areas.

It should be noted that it is simple to generalise the concept of synergy to that of synergy at radius R rather than 3. So synergy radius 4 is the correlation between integration at radius 4 against radius infinity. It is also possible to further generalise to synergy at Radius R against Radius T. So for example, Synergy Radius 4 against Radius 8 is the correlation between integration radius 4 and integration radius 8. Naturally, it is possible to enumerate between all values from 2 to G where G is the girth (maximum distance between any two nodes in a graph). This can be used to create a complete G-2 by G-2 table of all possible synergy values. This could then be regarded as an intelligibility surface with a diagonal ridge, where R = T, and so the correlation is of value 1.0. We will explore the use of R against T later; for the moment, when this thesis refers to synergy, unless stated otherwise it is referring to synergy radius infinity against radius 3 integration.

Given that synergy is also a function of a correlation or dot product, we must ask whether the synergy also changes with size. Plotting the same urban data set as intelligibility we produce Figure 8.10 above.

From this we can see that there is little dependence between system size and the synergy factor. With an R squared value for the correlation between synergy and size for the same kind of reciprocal behaviour being 0.065.

Point Synergy

Point synergy can be considered an analogy to point intelligibility. This can be defined as finding the set of lines centred on a single axial line and then finding the correlation between the value of radius 3 and radius infinity integration of the set of lines from the starting line. This value of correlation can then be applied as a measure or value back to the line, and then plotted like integration. As with point integration, the creation of the local subset centred on the line can be performed in a number of ways. It can be centred on the line via radius; that is by taking the number of lines up to three steps away from the starting point. Like point intelligibility, the number of lines within radius 3 can be variable and, as such, artefacts as discussed above can appear. To counter this, it is also possible to use the closest vicinity V of lines from the starting point. Doing this and plotting the value as an intensity colour back on the axial map gives Figure 8.11.

As mentioned in the definition of synergy, we consider the general synergy value to be between integration radius R and radius P, where P is generally radius infinity (a radius of the maximum depth or the diameter of the axial graph). Using point synergy, we now have three

Figure 8.17 Barnsbury 4 showing point noise map values ranging from 0.1 (red) to 0. (blue)

parameters that affect the function. Radius R, radius P, and the size of the Vicinity value V. By increasing V, we will be implicitly increasing the dimension (topologically speaking) of interest. This will reduce the number of possible regions and ultimately produce one region the size of the entire axial map. Given that each line will be using all other lines, the point synergy value will become singular for all points. That is the value of synergy for each line will be that of the system. This observation will be returned to later when we try to understand the meaning of point synergy.

If we examine Figure 8.12, we can see that the area known as Barnsbury stands out boldly from the surrounding environment. It takes a moment to realise that the only input to this visualisation was a map of pedestrian space free of any historical, land use, or visual information. Yet it appears to be returning a description of a named 'area'. Most significant is the presence of Canonbury, a local sub-area standing out from Barnsbury, Islington, and Highbury.

The bordering districts of Camden, Bloomsbury, and Holloway clearly are acting like a buffer zone around the central Barnsbury district. The values for Camden, Bloomsbury, and Clerkenwell are slightly different, but the colour scale used here is not fine enough to distinguish them. Clearly, like the movement based axial maps we must expect a 'buffer' area around a neighbourhood of interest for the borders to reflect the correct interactions between spaces to give the correct values for this window on a real city.

In the above image we can see a case where one neighbourhood, Barnsbury, appears to extend over into what would rightly be called a different neighbourhood, Islington. In this case, it is necessary to say that we are looking at what might be termed 'natural neighbourhoods.' Just as with the case of natural movement, we can say that a point synergy map with appropriate parameters shows the emergence of an unmodified or ideal neighbourhood from the configuration of a space before any attempt has been made to redefine the neighbourhood to suit other interests, such as those related to political or bureaucratic boundaries, estate agents, commercial distortions, or historical effects.

If we examine Figure 8.13, we can begin to explore how synergy is different from other neighbourhood measures. For example, we can see in the case of Chelsea, in the west end of London, that the central integrator (the route with the highest local integration, choice, and observed movement), Kings Road, sits at the centre of the zone of constant point synergy. This is also the case with Brompton Road in

Figure 8.18 Clerkenwell 1805, showing boundaries that would eventually become the core spatial network. Cartographer: James Tyrer.

Knightsbridge (same figure) but is, as will be seen later, an atypical example, as primary integrators like Oxford St in London also become edges of neighbourhoods as stated by Peponis. Figure 8.13 also shows a number of other areas in London, including Covent Garden (red zone at top left) and Fulham (yellow area at bottom left)

If we recomputed the same axial map, but this time use synergy with a radius of 4 and a vicinity of 180 (see Fig. 8.14), we can see that while we still have some distinctions (Fulham and Covent Garden for example), the areas are merging together. Clearly there will be values for the radius and synergy parameters where the entire west end will emerge as one unit (the West End). This reflects our notion of the containment hierarchy of place, the kind we use when trying to describe our home to a complete stranger (Europe, UK, London, West End, Chelsea...), something that cannot be described with the Peponis high choice edges description of neighbourhood.

Null hypothesis point noise or point randomness

When considering the operation and meaning of point synergy maps and point intelligibility maps it may be argued that the observed results are not entirely due to the fact that synergy and intelligibility reflect the way an urban environment is cognitively understood, but are rather the results of the choice of subset via radius or vicinity.

For example, if the urban environment was in the shape of a dumbbell, each bell containing roughly 10 axial lines and the bar being more than 3 axial lines long, then it would be reasonable to observe that the vicinity 10 would generate two largely homogenous regions in the bells. Inside these bells it would be very likely that the sets encountered would be roughly identical and so the correlation/dot product of values would match. This subset choice hypothesis would hold that the method for selecting the subset is the key to finding the axial lines and that the values chosen for correlation would be far more important than the syntactic measures chosen.

To test this null hypothesis (that synergy and intelligibility have no strong role to play in the observed phenomena), we can create two new columns of random values. These values are then used as substitutes for the 'connectivity' and 'integration' values in the intelligibility mapping process. Clearly, given that the values are random, they will show no indication of network structure. We would expect the correlation values to be low (r2 near 0.1). We ignore the absolute low values of correlation and consider the relative values. When looking at the maps we understand that we are looking at areas of similar correlation values. For example, in the dumbbell example of Figure 8.15, if all the nodes form an exclusive clique, then all the r2 correlation values would be low, but their values would be nearly identical to each other. For example, if we have a set of nodes

G = <a, b,c,d,e,f,h,j,k >

If for clarity we operate at vicinity = 4 (or radius 2), then the set starting from node a will be {a,b,c,d}. If we begin from node b, the vicinity set will be {a,b,c,d}, for c {a,b,c,d}, and for d the closest set may be {a,b,c,d} or {a,b,d,e},{a,c,d,e},{b,c,d,e}. Given that the scopes of the vicinity sets are similar, we would expect the correlation (r2) values to be identical

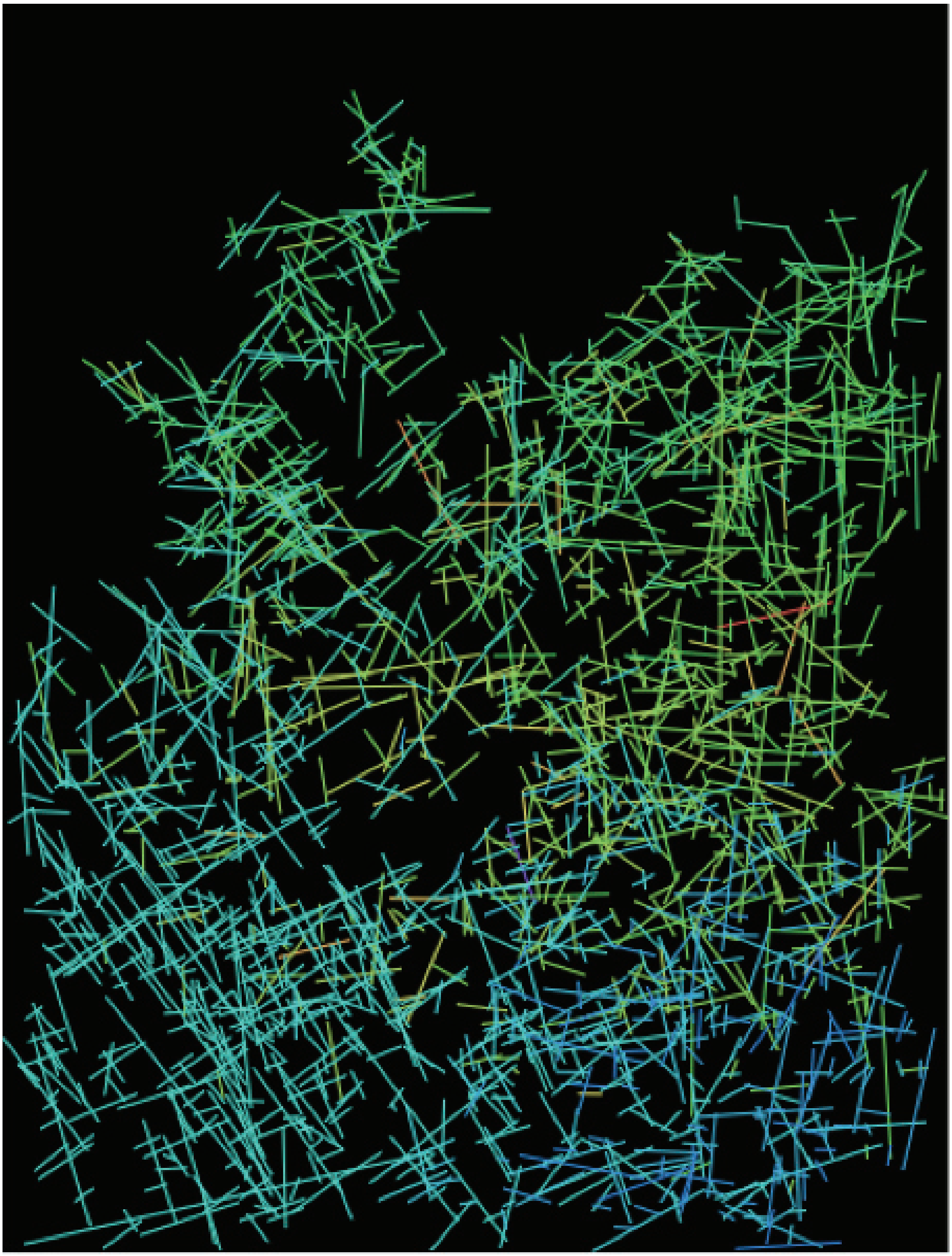


Figure 8.19 Randomised Barnsbury 4 showing weak regions of point synergy R=4, V=180.

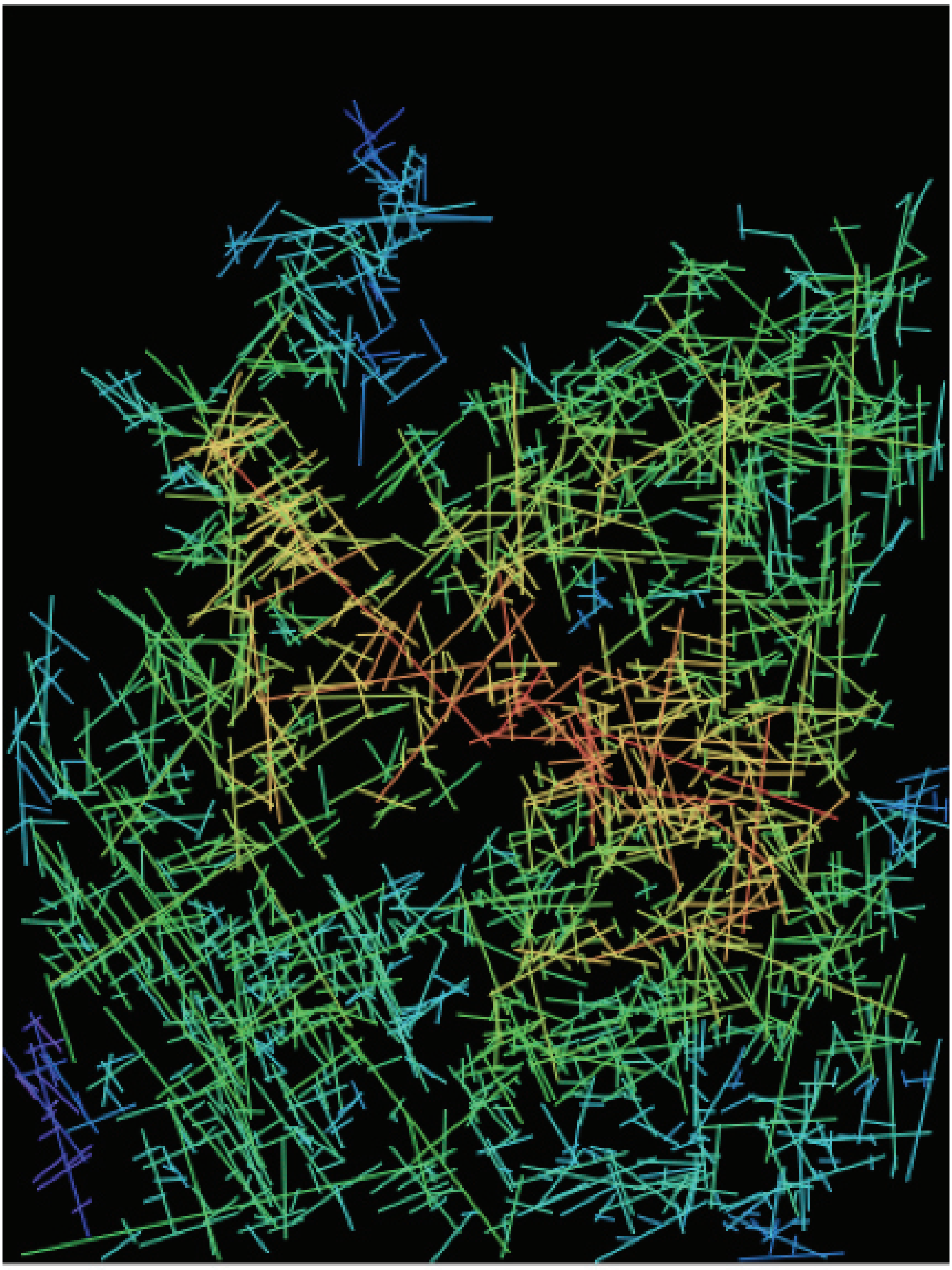


Figure 8.20 Integration map for Randomised Barns 4.

for identical sets – we will call this the structural scoping effect. In an extreme case, as Figure 8.16, clearly the existence of the clique is the dominant factor and this would be born out by the values of point synergy and point intelligibility. It would also be born out by the point noise values. In the urban context things are much less clear; generally there are few cliques in an urban context. Axial maps have a tendency not to be small worlds, small worlds by definition have high clustering factors and are highly transitive that is small world graphs have many links where if A links to B and B links to c then A is highly likely to link to C. These are common in social networks but with axial maps the axial lines would be have laid out to form a triangle to achieve this. While axial maps are strongly clustered at a higher level (If A knows B and B knows C and A knows D then it is highly likely that D knows C) applying the term 'small world' to them could be considered an over-generalisation given that it would mean leaving behind most of the interesting results that have been found for this class of graph. Given the lack or small world properties for graphs derived from axial lines (where the number of close cliques is high) the only point where a clique forms is a multi node junction. It is possible to, create and visualise a point randomness map (using the webmap@Home application specifically programmed for this thesis), as shown in Figure 8.17.

From this we can make a number of tests. First, visual inspection shows that the there appears to be a general lack of structure, except for the bottom right corner for Somers Town/Mornington Crescent/Bloomsbury and portions of Kings cross. Second, examining the correlation between values of point intelligibility and point synergy generates an R squared of 0.5134. This suggests that the areas suggested by point intelligibility and point synergy broadly correspond. The correlation of point intelligibility against point noise is 0.03311; against point synergy the correlation is 0.02371. This is consistent with the hypothesis that the structural scoping effects only have a small impact on point synergy and point intelligibility maps.

Urban randomisation test

If the patches of constant point synergy or point intelligibility are due to some property of synergy and intelligibility, not to the local correlation finding process (as described above), the next objection that could be raised is that it is the very nature of the axial line giving rise to self-organising properties. In simple language, is it the very fact that streets exist that gives rise to the synergy and intelligibility patches, or is it how the streets are arranged? It has already been mentioned that by their very geometrical properties axial lines are not natural small worlds and that some of the graph properties are due to the process of axial intersection, so the objection cannot be immediately dismissed.

The linkage between the rise of regions of constant intelligibility and synergy can be tested in a fairly simple way. We might argue that the spatial configurations we find in cities and urban environments from axial maps from around the world are an inevitable consequence of the conditions that determine the length of space/street and so axial line. For example, it might be argued that local environmental conditions, such as wind and sun, might give rise to a large number of orthogonal spaces/streets and so axial lines. It is known that there are some regularities in the orientation of axial maps (Penn and Croxford 1998), and even in highly irregular settlements like London we will see a predominance of North/South and East/West lines.

We might also argue that the distribution of connectivities is a natural consequence of the length of lines. There are a few long lines and a large number of short lines. It is quite reasonable to expect that longer lines will have higher connectivities due to the inevitable process of intersection; a longer line is likely to intersect more in a given area. Further, we might well expect that the average connectivity is more linked to the distribution of line lengths in a given area. For example, if the same number of lines lies in a large geographic area then there is less necessity for the lines to intersect and we would expect the average connectivity to drop if the density drops. Indeed there are those that presuppose (Penn and Carvalho 2004) that the axial line length structure, or the distribution of axial line lengths, is so fundamental to the structural properties of spatial configuration that it is only necessary to examine the distribution of line lengths to gain insight into the spatial configuration of a city.

We might imagine that it could be possible to randomly generate an axial urban environment that matches some predetermined pattern or distribution (such as those described by Penn and Carvalho). We might generate the correct distribution of axial line lengths, orientations, and so on in a given area and then test that axial map for the intelligibility and synergy properties. If the point intelligibility and point synergy patches constantly appear then it would be logical to presume that the network inherent from a graph derived from an axial map naturally gives rise to these properties. A simpler generative method is proposed here, namely to 'randomise' the axial map. An axial map of a real location can be randomised, that is all the lines can be randomly moved from their original positions. This randomisation can and should have a number of constraints.

That the orientation of the lines is maintained. That is the likelihood that too connected lines were orthogonal to each other is maintained. The lines retain their original length. This keeps the distribution of axial line lengths to those strictly found in real axial maps. The density of axial lines is maintained. This means the bounds for the randomised axial line are the same as that of the original map. This can be approximately achieved by keeping the axial lines within the same bounding box (area) as the original axial map. If a line is moved randomly outside the area, it will be moved back. The condition is imposed on the graph that the system be fully connected. This is achieved by performing a test on full connectivity on new axial lines, and if the line fails, it is repeatedly moved until it is connected. Figure 8.19 shows the typical result of randomising the axial map of Barnsbury. It can be seen from Figure 8.19, in comparison to the original version, that if the system is randomised then only weak regions are found in comparison to the strong regions found in the original map. The conclusion that can be drawn from this is that the structures or neighbourhoods found in the axial maps are not consistent with the hypothesis that they are the random and inherent result of the simple presence of axial lines. This supports the conclusion that the neighbourhood structures found are non-random results of the emergent pattern of local and global actions over the evolution of the urban fabric.

The field of clustering, or partitioning, is a rapidly developing one, but the review presented here does support the assertion that the point intelligibility/point synergy method presented here does appear to be new, novel, and currently unique. That is given the proviso that the type of graphs and the type of clustering desired does appear to be predicated on the rather special properties of the axial maps considered in the field of space syntax. Clearly, there are a number of methods that can partition the graph of the axial map into various communities. The key question is whether these regions or neighbourhoods reflect the kinds of neighbourhoods found in the real world. This question will be addressed in the next chapter.

Summary

This chapter began with the first part of the place hypothesis, that a place to be recognisable as such must possess some continuity of character that differentiates it from the surrounding urban landscape. It went on to discuss the Hillier definition of a well formed neighbourhood as having the property of intelligibility and synergy. These terms were introduced and a new mathematical formulation of intelligibility was introduced. The chapter went on to look more closely at intelligibility, and with the aid of visualisation via intelligibility dimension curves and intelligibility profiles, identified that it was composed of two components, extrinsic intelligibility, which changes with size, and intrinsic intelligibility, which is independent of size (scale free).

Using a process derived from an intelligibility profile, it was found that a new mechanism could be used to produce maps that, while flawed, appeared to group neighbourhoods (in the social sense) via continuous values of point intelligibility. This new mechanism is called point intelligibility – the intelligibility of a group of node/axial lines within a fixed radius to a starting node/axial line. To refine this, the concept of vicinity was introduced and applied, producing more representative neighbourhood maps.

This process was repeated with synergy, creating point synergy maps as a system that appeared to also identify neighbourhoods. It was then shown that this was not merely an effect of the point aggregation mechanism, as attested to by the null point noise or point randomness measure. The neighbourhoods discovered were also not the result of the inevitable process of the intersection of axial lines, as the urban randomisation test demonstrated.

The methods of point synergy and point intelligibility were shown to be original new contributions to the mechanisms for finding graph neighbourhoods (in the mathematical sense).

Key Points

- The first part of the place hypothesis needs for a continuity of character.
- The Hillier notions of intelligibility and synergy appear to supply a possible mechanism for this.
- A new formulation for intelligibility was suggested.
- Using an intelligibility profile it is possible to unpack the intelligibility of a configuration separating the impact of size from that of pure scale-free complexity.

A restricted subset of a system from a starting point called point intelligibility and point synergy was introduced.

To allow for different sizes a mechanism of vicinity rather than radius was introduced.

The point intelligibility and point synergy maps appear to identify neighbourhood-like entities.

Evidence was presented to show that the effect was not the result of aggregation mechanism.

Evidence was also presented to show that the effect was not the inevitable process of the intersection of axial lines.

Chapter 9:
Observing Neighbourhood Boundaries

Summary

This chapter reports on experiments conducted to see whether the regions defined by point intelligibility and point synergy are linked to the regions reported as neighbourhoods. The first experiment compared the centres of the regions of continuous point synergy and point intelligibility to the locations of named neighbourhoods on Ordnance survey maps. While this method appeared to provide a large scale confirmation of the theory for a number of UK cities, it did not provide a definite test for the theory. A second experiment, involving using the neighbourhood regions reported by Lynch for the area of Beacon Hill in Boston, suggests that differing parameters of synergy appear to find the larger scale neighbourhood (Beacon Hill) and the two sub-areas (north side and south side) contained therein. Finally a method is developed from this which surveys inhabitants then processes the responses to find what is called a 'consensus neighbourhood' which can then be statistically compared to point synergy and point intelligibility maps.

Introduction

In the previous chapter, the concept of using intelligibility and synergy as the markers of well formed urban areas was introduced. It was then expanded to build the concepts of point intelligibility and point synergy. This raises a question - If a space has natural boundaries, do these boundaries reflect those perceived by the local inhabitants? This chapter introduces empirical evidence to support the hypothesis that neighbourhood areas can be identified from purely spatial configurations.

In the previous chapter, we introduced the concept that it was possible to use point intelligibility and point synergy to identify apparently natural neighbourhoods. That is, the kinds of natural neighbourhoods that spontaneously arise and are largely self-organising, rather than those that might be externally imposed or distorted. This chapter examines whether it is possible to test whether the kinds of areas identified by the point intelligibility and point synergy methods actually approximate the way the neighbourhoods are experienced. It should be pointed out that no previous methodologies have been established to rigorously and objectively identify a neighbourhood given an arbitrary spatial measure. Hillier (Hillier 2007) did visually compare a proposed segmental Mean Metric Depth (MMD) method to known areas in London (similar in method to that described below), concluding that "At an intuitive level then there seems quite a strong agreement between the patchwork and functional variation, even at this small scale". Hillier's intuitive method (discussed in a variation later in this chapter) could be criticised as lacking in rigour. If randomly placed patches were presented to an expert might they also find regions which appeared to coincide? Hillier's test was admittedly at an "intuitive level" leaving the field open to more objective and rigorous tests, which this chapter attempts to begin.

Previous research has attempted to establish the geographic area of a neighbourhood, but this was always done as a part of other areas of research. Taylor (Taylor, Gottfredson et al. 1984) made a sociological attempt to identify neighbourhoods as geographical areas as a part of a wider examination into the perceptions of neighbourhood. Taylor did not report any significant results from the geographical data, except to suggest that respondents might place themselves at the centre of their neighbourhood. Given the background of this research, it is unlikely that Taylor had the resources to perform a strongly crafted geographic analysis. The work of Lynch (Lynch 1960) is better known, but was also done as a larger survey of the perception of space. Lynch's work focused on the concept of finding those elements that contributed to 'legibility' and had little interest in establishing the extent of a neighbourhood.

When considering how to test the point intelligibility and point synergy methods, we suffer from a number of problems. Firstly, the point intelligibility and point synergy methods do not create definite boundaries, but just areas of local consistency. Secondly, the kinds of bounds found on maps, such as ward boundaries, are likely to be imposed (institutional), rather than a measure of the spontaneous intuition of inhabitants in relation to their notion of their area. For example, from an institutional and governmental view, are unlikely to have a hole in a neighbourhood, or strong interpenetration of neighbourhoods. Because of this, ward boundaries, which would be a tempting starting point, are poor guides to the local morphology of neighbourhoods. See Hanson's Theses (Hanson 1989; Hanson 1989) for more on this. This makes it necessary to explore ways to make the comparison with the ground truth, and this will be done through a number of methods listed below.

This thesis will cover three methods which attempt to test if the regions identified on the axial map reflect the neighbourhoods they appear to cover.

Named neighbourhoods method

This method is an extension of that used by and Yang and Hillier (Yang, T., & Hillier, B. 2007) as a test in their paper, except that in this case the Ordnance Survey map neighbourhood name is used rather than personal local knowledge. It is a simple statistical test if the named regions are accurately found. This method has the advantage of providing a test over a number of named neighbourhoods of cities over the UK providing a broad but not accurate test.

The neighbourhood Z-test

This test assumes that a single region for the neighbourhood is known prior to the test. The Z statistic tests if the region within the bounds is a random sample of all the maps axial line values (for example point synergy, point intelligibility, mean integration, EMD) or is a non-random subset. This method is a more detailed test than the broad neighbourhood names method but requires knowledge of a single neighbourhood boundary.

The selection connection method

This method assumes that the named region is known as in the neighbourhood Z-test with axial lines that lay within it as the 'gold standard' The method then creates a subset of the axial map by seeding one axial line in the region then finding connections of connections (similar to friends of friends in a social network) which have similar values. This subset is then used as a test subset. A Chi-squared test is then applied to the table of true-positives, false-positives,true-negatives,false-negatives to give a statistical test of neighbourhood accuracy. This method is detailed but choice of line and nearness value limits reproducibility.

Link based agglomerative hierarchical clustering

This method is an extension of the selection connection method (using Chi-squared test). It uses a modification of the Romesburg agglomerative hierarchical clustering method to group all the axial lines in an axial map into groups (clusters). The group within the known neighbourhood is then tested using the Chi-squared method. This method is quite detailed, is more reproducible than the selection-connection method and is used in the remainder of this thesis.

Each testing method has its advantages and disadvantages discussed and through elucidating the development of these methods it is hoped to stimulate further work on this field. All the axial tests require knowledge of the true neighbourhood area. To do this it is necessary to record the inhabitants' impression of the boundaries and convert these into a single bound. To do this a new direct observation method is introduced later in the chapter. A second method will be presented which will construct a single boundary (called the consensus boundary) by merging all the reported neighbourhood boundaries will then be presented.

Map neighbourhood names method

The first method is an initial probe into one potential mechanism. This could be seen as a variant of that mentioned by Hillier (Hillier 2007) looking for correspondence between geographic visualisations of measures (MMD or in this case point intelligibility and point synergy) with known neighbourhoods. In this case there is an attempt to be more objective by removing the necessity of expert local neighbourhood knowledge. It can be observed that the Ordnance Survey of the UK (Survey 2001) presents neighbourhood names on their maps. The mechanism by which names are identified and applied is unclear but they are certainly present. The first test then would be to identify areas that the Ordnance Survey has recognised and determine whether they appear to be in areas of continuous point synergy and point intelligibility.

The fault with this method is that while the Ordnance Survey has presumably identified the centre of a neighbourhood, they have not identified its extent. So a method could be used to draw a circle whose centre is at the centre of the OS neighbourhood label. For the OS the size of the font for the label appears to be related to the neighbourhood's size; larger point size generates larger circles. Circles were reduced in side or elongated into ovals when they appeared to overlap strongly with another label or if other geographic needs (such as the presence of rivers and main roads) demanded.

The test then becomes an assessment of whether the area inside the circle is a region of continuous point synergy to point intelligibility.

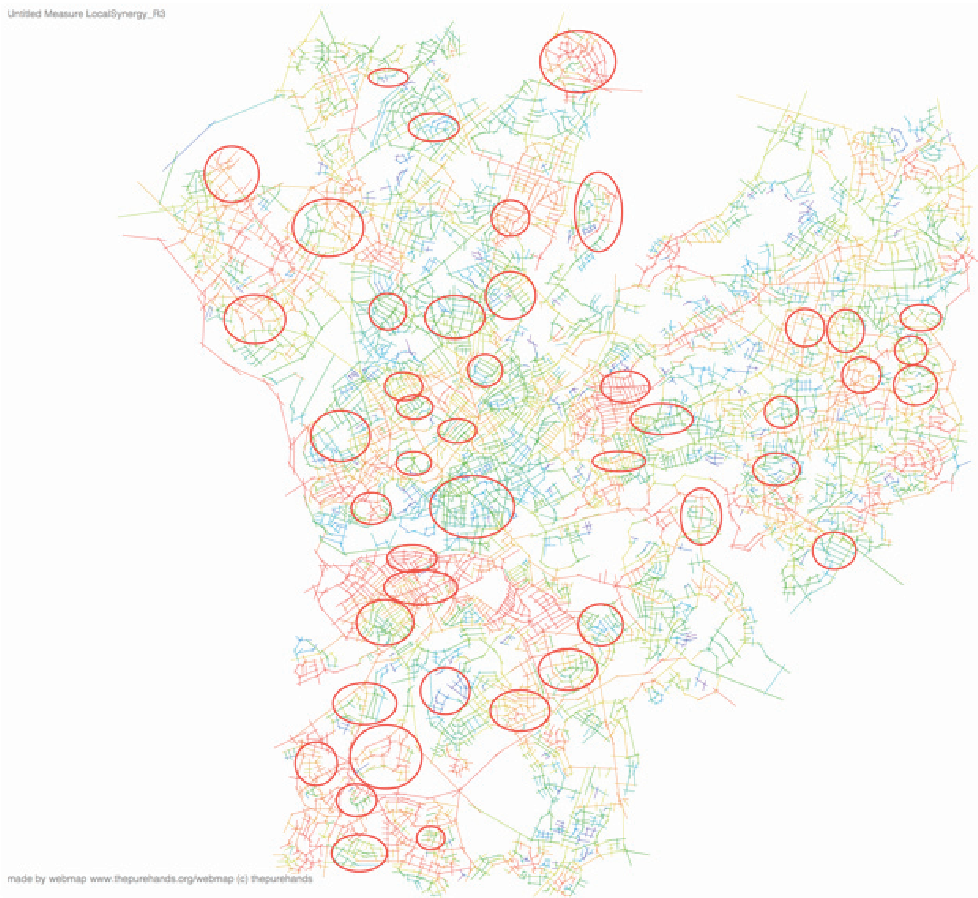


Figure 9.1 Areas of Neighbourhoods from OS maps against Axial map Synergy R=3, V=90.

The Ordnance Survey neighbourhood markers were taken from examining the maps available online at http://www.ordnancesurvey.co.uk/oswebsite/getamap/. These were then compared to previously digitised axial maps available in the Axial Urban Database. The values for point synergy were then visually inspected to see whether the area within the circle was uniform in colour (i.e of constand point synergy value). Fig. 9.1 shows a sample axial map labelled with the estimated neighbourhood areas in red circles. This process was repeated for a number of UK cities and the results are presented in Table 9.1. From this, it can be seen that 39 zones were established as incorrect (the area was considered not to be uniform) and 163 areas were considered to be correct (the area within the zone was considered to be generally uniform).

A number of observations were made during the performance of this initial test. First, it became apparent that synergy R3-V90 performed more accurately than intelligibility in the identification of zones of continuous value. Second, some of the neighbourhoods from the OS map that failed to be correctly identified were ones that appeared to be newly created. Again, it was difficult to establish the authenticity of the named areas, for example a zone like Oxford Leyes Estate had the name of the project and spatial region imposed by architectural and local authority planning. It is natural that

City	Measure	Correct	Incorrect
Oxford	synergy	21	4
Wolverhampton	synergy	39	12
York	synergy	14	1
Bristol	synergy	34	11
Cambridge	synergy	8	0
Norwich	synergy	16	2
Newcastle	synergy	23	9
Manchester	synergy	8	0
Total		163	39

Table 9.1 Results of approximate locations of neighbourhoods from OS maps.

such largely constructed zones, rather than natural neighbourhoods, would become part of the general lexicon of the OS, leading to potentially false negative results (places that the inhabitants would not perceive as neighbourhoods that have neighbourhood names on the OS map).

Like the Hillier method which shares a number of similarities this OS names method then should not be seen as a strict test for the confirmation of neighbourhood identification but as a lightweight early rejection test. This is as Hillier states test of agreement at the intuitive level. While the test is methodologically primitive, it is certainly simple enough to be performed independently by anyone for an alternative measure of neighbourhood and can be used for quick rejection tests. In other words, a poor area finding procedure would quickly be rejected by this method. The primary advantage of this method, over those presented later, is the breadth[1] that it gives, compared to the detail of the methods presented later in the chapter. This method was used to survey a number of English cities, but suggest that the results of the later studies appear to be representative of UK urban environments as a whole.

The results are presented in Table 9.1. Given the four to one ratio in correctly identified OS neighbourhoods to those established by the synergy mapping measure, it could be said that it is consistent with the hypothesis that point synergy based continuity areas correspond to neighbourhoods.

It would be possible to refine this and the Hillier methods by as mentioning testing a number of patch making methods in a manner of a placebo-like blind test. For example a panel of experts could be given maps which represent the genuine regions and other maps which represent fake regions and asked as a comparison. However, given the inherent dangers in each method (expert knowledge or OS

Figure 9.2 Acorn Street, Beacon Hill, Boston, Massachusetts. These houses were built in the late 1820s by Cornelius Coolidge.

1. Ability to look over a large number of cities and neighbourhoods rather than the detail of each individual test.

neighbourhood knowledge), it appears more logical to spend effort on the more rigorous and objective methods developed below.

Case Study: Beacon Hill

The primary criticism of the first assessment is that while it covers 202 neighbourhoods, it does so using a nearly arbitrary estimate for the extent of the neighbourhood. A stronger test would involve surveying a number of residents and discovering from them where their neighbourhood started and stopped. This kind of test was performed by Lee (Lee, 1973) in Oxford in the 1960s, but unfortunately none of that original data is available. A secondary criticism of the data presented above was that this was for a sample of UK cities and that the point synergy and point intelligibility mechanism presented might only be suitable for British, or possibly European, cities.

Kevin Lynch's The Image of the City (Lynch 1960), reviews work performed by Lynch on the neighbourhood known as Beacon Hill in Boston, Massachusetts, USA (see Figure 9.2). In his book, Lynch relates a methodology where twenty local inhabitants of a neighbourhood were interviewed to assess the extent of the neighbourhood. These street interviews of residents or those employed in the area tried to assess what Lynch called the imageability of the neighbourhood. This included descriptions, locations, the performance of imaginary trips and sketches of the area (Lynch 1960 pg 17). A component of the interview was an assessment of what streets defined the boundaries of the neighbourhood (remember that Lynch had boundaries and districts as one of the five elements he was trying to assess). From these interviews, Lynch showed that the extent of Beacon Hill was rather well known and largely agreed upon, something that was not true for other areas in Boston. The interview process revealed that two primary sub-areas existed, known as Front-side and Back-side or North-side and South-side (respectively).

These sub-areas were known to have identities stretching back to the antebellum period, with the north side known as Black Beacon Hill, with presumably the south side being White Beacon Hill, although the two sides were supposedly united after the abolition of slavery and this is now the location of the Museum of African American History. This area of approximately 2.6 km^2 is home to about 10,000 people, as well as the Massachusetts State House. Beacon Hill was designated a National Historic Landmark in 1962 and is currently reputed to have some of the highest property values in the United States. This is strongly suggestive that the area of Beacon Hill is both a neighbourhood and one super-neighbourhood containing two sub-neighbourhoods. More importantly, it shows that there appears to be a sense of attachment to the locale that is indicative of it being an authentic place. One of the things that is of interest is that the sub-areas appear to have separate identities running back to at least the Antebellum period (~1854), and that these informal sub-areas appear to exist today (Withington 2006), in spite of the fact that for parts of the neighbourhood considerable changes in use, occupation and building types have taken place.

In the 1960s, Lynch interviewed locals and asked them to establish the location of the general Beacon Hill neighbourhood and those of the Front side and Back side areas. These maps of neighbourhood areas were presented

Figure 9.3 Global axial integration map of Boston after Raford & Hillier, showing the area marked by Lynch as Beacon Hill in white bounds.

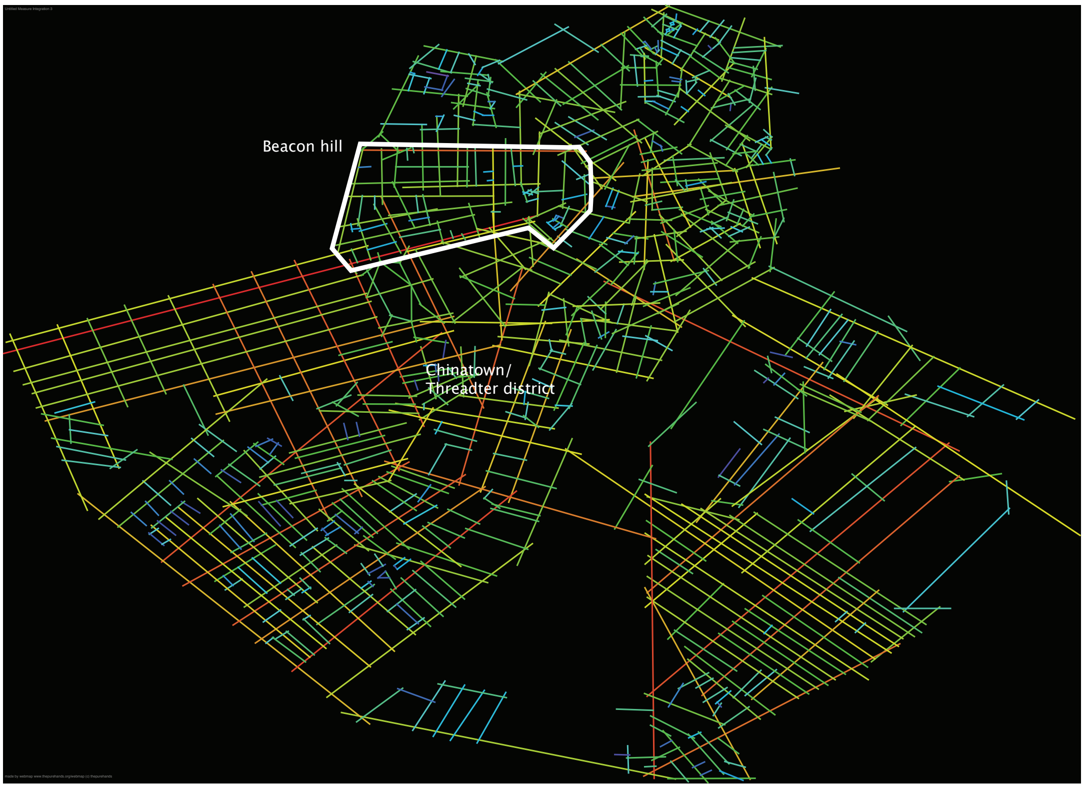


Figure 9.4 Radius 3 integration map of Boston after Raford & Hillier, showing the area marked by Lynch as Beacon Hill in white bounds.

Figure 9.5 Global axial choice integration map of Boston.

Figure 9.6 Point Intelligibility Map V50 map of Boston after Raford & Hillier, showing area marked by Lynch as Beacon Hill in white bounds.

in an appendix of The Image of the City (Lynch, 1960). The area and the surrounds of central Boston were axially mapped in 2004 by Noah Raford (Raford 2005; Raford 2005). This is presented below. The axial map was donated in the Mapinfo format from the author. The MIf format was converted to DXF and imported in version 1.2 of webmap@home (Dalton 2005; Dalton 2007). The software for the computation of both the standard integration measures and the new point synergy measures was entirely written by the author and the source code and webmap@home (.AXL) maps are attached in the accompanying digital media.

An inspection of the map in Fig. 9.3 shows that there is little about the global movement scale that appears to indicate that the neighbourhood of Beacon Hill can be identified by observing movement alone.

The radius 3 map in Fig. 9.4 shows an area of no distinctive character in terms of local movement. Quite the reverse, this area shows quite a diversity of integration patterns, which Hillier indicates is indicative of a 'good' area (Hillier 1996).

We can process the map with choice at radius infinity (see Figure 9.5). We can see that, in this case, the map is consistent with the Peponis hypothesis that areas of high choice form boundaries between neighbourhoods. Yet, other areas such as the Theatre district around Tremont St appear to be intersected by them.

Vicinity Parameter

If we now introduce the point intelligibility map, we must try to fix an appropriate vicinity parameter (V). As mentioned, vicinity is a mechanism to permit the direct comparison of areas of different sizes around a starting node. No mention has yet been made of what the appropriate value should be. So far in this thesis, following the technique used by Hillier(Hillier, Turner et al. 2007, Yang & Hillier 2008) the vicinity parameter has been processed over a number of levels and the most visually promising has been used as basis for analysis. The question then arises: is there some basis for choice of a vicinity value?

The previous work on the creation of vicinity dealt with it as a means of producing axial angular integration (Dalton 2007). In space syntax, it is generally held that a radius of 3 typically represents the kind of movement patterns of pedestrians. In the absence of direct observation values (for example when looking at the movement patterns of historic settlements where only archaeological remains exist), a value of 3 is typically held as a valid starting point. The value of global movement (also known as radius infinity) is held to correlate well with global movement patterns, such as vehicular transport, although in London, Penn (Penn, Hillier et al. 1998) found that a value of radius 8 appeared to correlate better with observed vehicular movement.

To produce a similar value for vicinity, it would be necessary to compare the correlation coefficient of observed pedestrian movement against a range of different vicinity values, looking for the one that correlated more consistently over a large sample of cities and conditions. This kind of direct observational material is hard to ascertain and has poor meta documentation. As such, no statistical sample of movement data is available. In the absence of this data, it was necessary to compare the vicinity value against that of the radius 3 integration value.

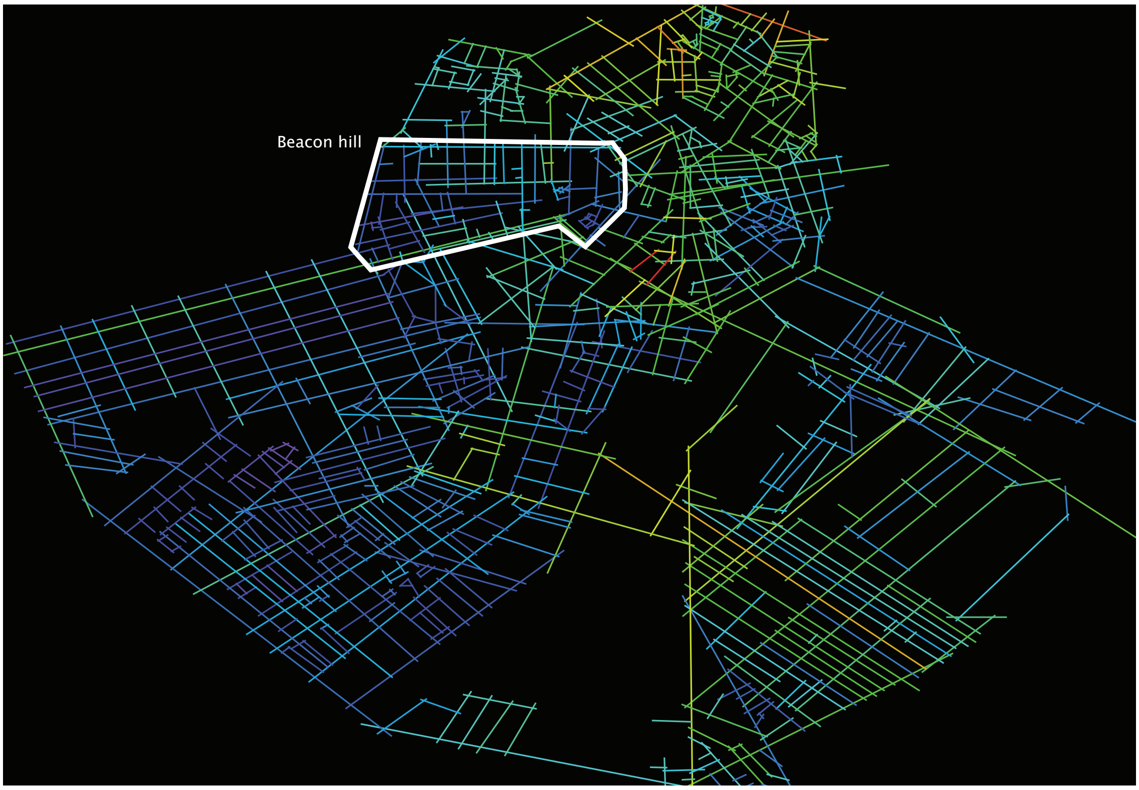


Figure 9.7 Point Synergy Map V50 map of Boston after Raford & Hillier, showing area marked by Lynch as Beacon Hill in white bounds.

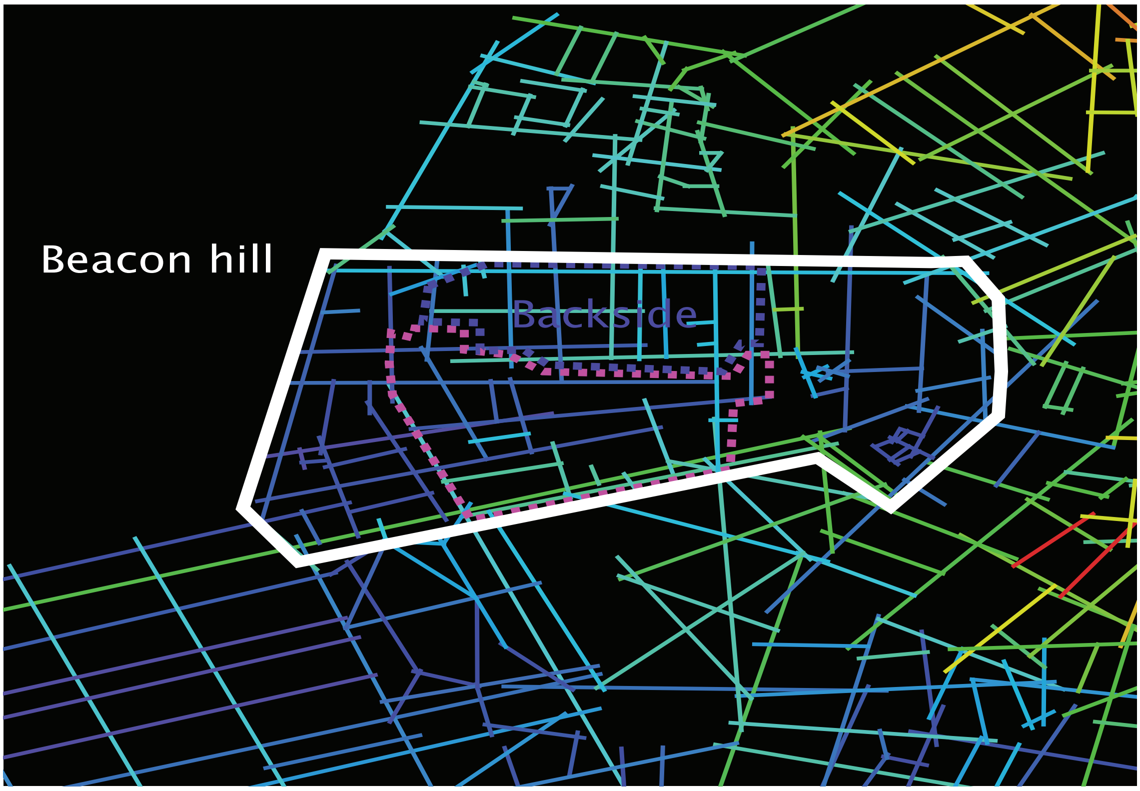


Figure 9.8 Beacon Hill area of Boston, showing front-side and back-side neighbourhoods in dotted bounds, axial lines coloured by point synergy V=50.

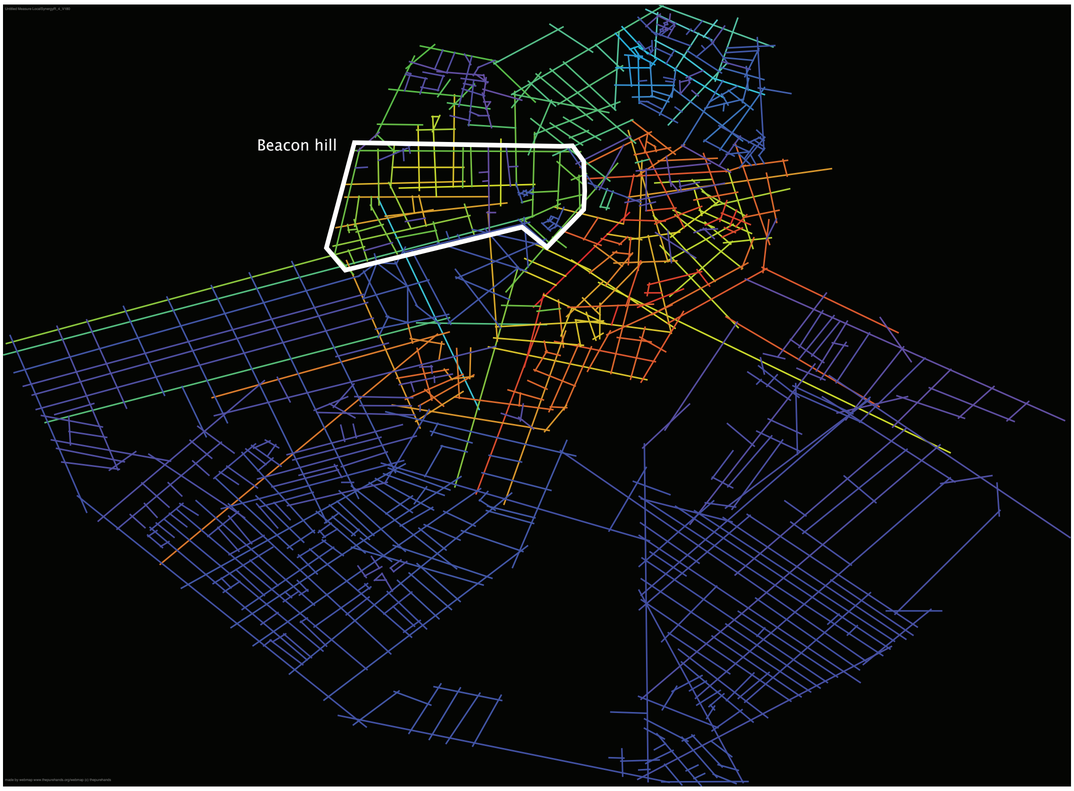


Figure 9.9 Point Synergy map V180 Radius 4: infinity map of Boston after Raford & Hillier, showing area marked by Lynch as Beacon Hill in white bounds.

A number of axial line maps were examined and it was found that generally a vicinity parameter of 90 (closest 90 axial lines) tended to correlate well with the integration radius value of 3 (when comparing integration radius of 3 with 1 / Vicinity (V)). Repeating this test for Boston, it was found that a vicinity value of 50 gave the highest correlation with a radius of 3 and an R2 of 0.9236 between radius 3 and the reciprocal of vicinity V = 50.

Point Intelligibility Mapping of Boston

The axial map in Fig. 9.6 was produced by using a value of 50 for the vicinity value in the point intelligibility calculation. As a side note, the small red region covers what some tourist maps refer to as the ‘theatre district’. While a theatre district is not a neighbourhood that is experienced its existence as a named region certainly suggests the capture of something relating to place.

Two comments could be made about this map. The area of Beacon Hill identified by Lynch and marked in white on the map does not appear to have a completely uniform point intelligibility value (the colour and so value shows small variations). While the zone does appear to be distinct from the space to the south and west, the northern border appears to be mid-way through the space.

Point Synergy map

Turning to a point synergy (see Fig. 9.7) map for help, we find a very similar condition. In fact, when comparing values, we find an R2 of 0.7876 between point intelligibility V = 50 and point synergy v = 50.

While part of the Beacon Hill area appears to be a continuous blue colour, we find that it does not extend to the entirety of the Beacon Hill bounds. If we now ignore the extent of the city and focus our attention on Beacon Hill itself, introducing the sub areas Lynch discovered, we find a slightly different picture.

Examining Fig. 9.8, we begin to see that in the v = 50 point synergy map, the back-side area is largely consistent and the front-side area, while not complete (the area to the left also has the same value of point synergy), is also consistent within the bounds that axial mapping permits.

From this, we may conclude that we have identified, not the large scale area, the area of Beacon Hill, but the sub-neighbourhoods that spontaneously arose and were first identified in the Antebellum period. Reviewing this using a purely spatial axial map of Boston constructed by an independent party with no knowledge of its use as a neighbourhood, we found that the point synergy values computed over the entire map were consistent across the area reported by Lynch after interviewing inhabitants of the two sub-neighbourhoods. Given that both the spatial axial data and the observations made by Lynch predated the analysis, we can dismiss the possibility that foreknowledge of the neighbourhoods was somehow inserted unwittingly or subconsciously into the axial mapping process. We can also dismiss the possibility that there was bias in the collection of the reported neighbourhood boundaries when the computed extent was known. This also subsumes a criticism of the first test that the neighbourhood finding process might only work for English Cities. This does give rise to a question as to whether the bounds of Beacon Hill can be found in some objective way or are simply historic cultural indicators showing that the entire area was once owned by William Blaxton in 1635.

As mentioned in the previous chapter, the point intelligibility method has a parameter of vicinity that defines the locale for the region. For the synergy measure, the value is augmented by needing to know the radii at which the components for synergy are computed. Typically, these are radius 3 and radius infinity, which are the relationships showing the significance of a street to the pedestrian and the entire global system. We can change these values and, if we expand the parameters, can encompass a larger horizon or region. We can then observe a continuum of changes in the pattern and distribution of point synergy.

From Fig. 9.9, a plot of the point synergy values for radius 4:infinity and a vicinity of 180, we can see that while the region of Beacon Hill is certainly intersected with large axial lines, the two sub-areas have merged into a general continuity, with a value of approximately 0.72. We can also notice that another neighbourhood, known as 'North End' (top left white bounds on the map), mentioned but not located by Lynch, is also now a region of near continuous blue (representing a value of 0.7836). It is interesting to observe that the red district appears to be that of the Central Business District of Boston, although it is hard to assert this with any great veracity as the area is only described as 'downtown' and can only be found on a few tourist maps, and even then the extent of the district is not given.

Even at these high levels of radius and vicinity for point synergy, we still see that lines

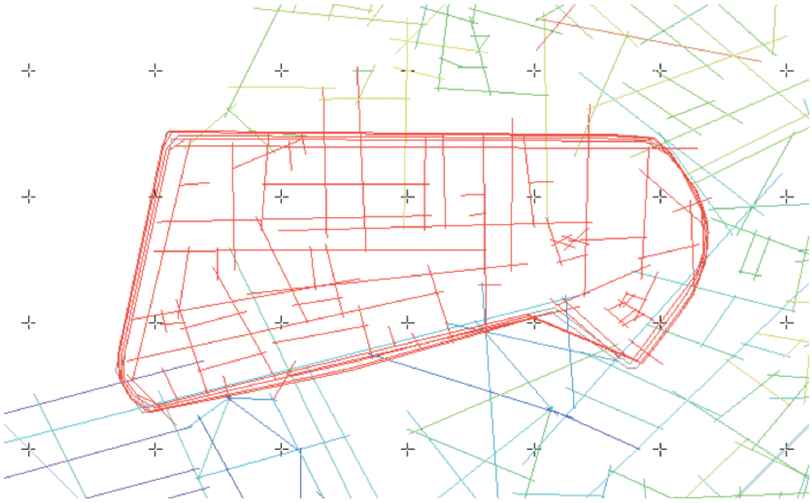


Figure 9.10 Map showing axial lines selected (in red) from Lynch's Beacon Hill bounds.

Figure 9.11 Beacon Hill front-side/south-side with Lynch boundary in red and included axial lines in red.

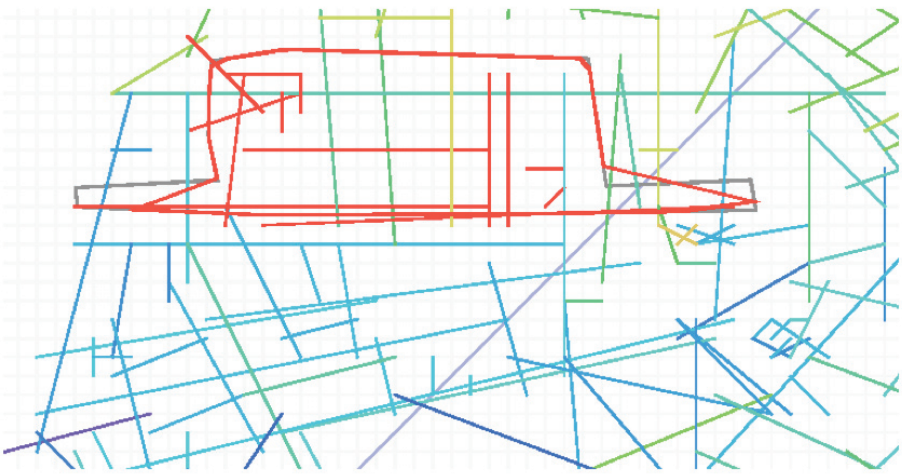


Figure 9.12 Beacon Hill back-side/north-side with Lynch boundary in red and included axial lines in red.

of a different colour penetrate the bounds. It can be supposed that if the values could be computed in a segmental way, the long axial lines passing through a neighbourhood could be eliminated and a higher resolution picture could be obtained (as happened with the angular segmental analysis with pedestrian movement data). (Yang 2006) gives an analysis of Lynch's work using an independent segmental mechanism that appears to be measuring the same neighbourhood phenomena as this thesis. As of writing this thesis Yang has not presented any statistical test for the accuracy of the segmental EMD method.

Statistical testing for neighbourhoods using the Z-test method

The visual test appears to be promising, but it could be criticized as being a subjective assessment, rather than a qualitative one. The visual assessment can be aided by a statistical test. If the hypothesis that areas of constant point synergy or point intelligibility do correspond to the Beacon Hill neighbourhoods, it should be possible to make a statistical test about the area. If the borders approximate each other, we would expect that the values for point intelligibility within the bounds given by the independently reported social bounds would be more uniform within the area than without. Assuming that no large areas of similar point intelligibility exist, we would expect that the sample of point intelligibility and point synergy values within the bounds would be statistically different from the surrounding areas. Thus, we can use a Z-test to test the likelihood that the lines were selected randomly from the population of all axial lines in the Boston axial map. Additionally, we would expect that the area defined by Beacon Hill would be more strongly linked with the higher synergy values.

Using a feature of the software application Interstice (Dalton, 2004) we can test the lines within the bounds provided by Lynch. One problem that is apparent is that due to the lengths of very long axial lines, for example Beacon Street and Storrow Drive, lines that intersect the boundary but are not a part of the system, such as Merrimac St., are unlikely to be part of 'Beacon Hill'. To counter this, the software assumed that only lines that have 50% or more of their length within the bounds of Beacon Hill were to be treated as 'within' the area. Fig. 9.10 shows a screen dump of the Interstice program after the Beacon Hill area defined by Lynch was used to find a sample of 75 lines from the Boston Axial map.

As mentioned the vicinity value of 180 R=4 appears to reflect the broader region of Beacon Hill (rather than the more local North side/ South Side neighbourhoods). By examining the axial map it was observed that examining this set, we find that the value for Synergy Radius 4 Vicinity = 180 is Z = 2.329 (sample average = 0.7700, sample stdDev = 0.01844, sample size = 75, population average = 0.7750, stdev = 0.02354, sample size = 751), which gives a greater than 95% likelihood that the sample is not a random sample for the population. For comparison, the Z value for a non-neighbourhood value, such as integration, gives Z = –0.60565, well within the limits of a random sample. It should be noted that the values for intelligibility and synergy do approximate a normal distribution.

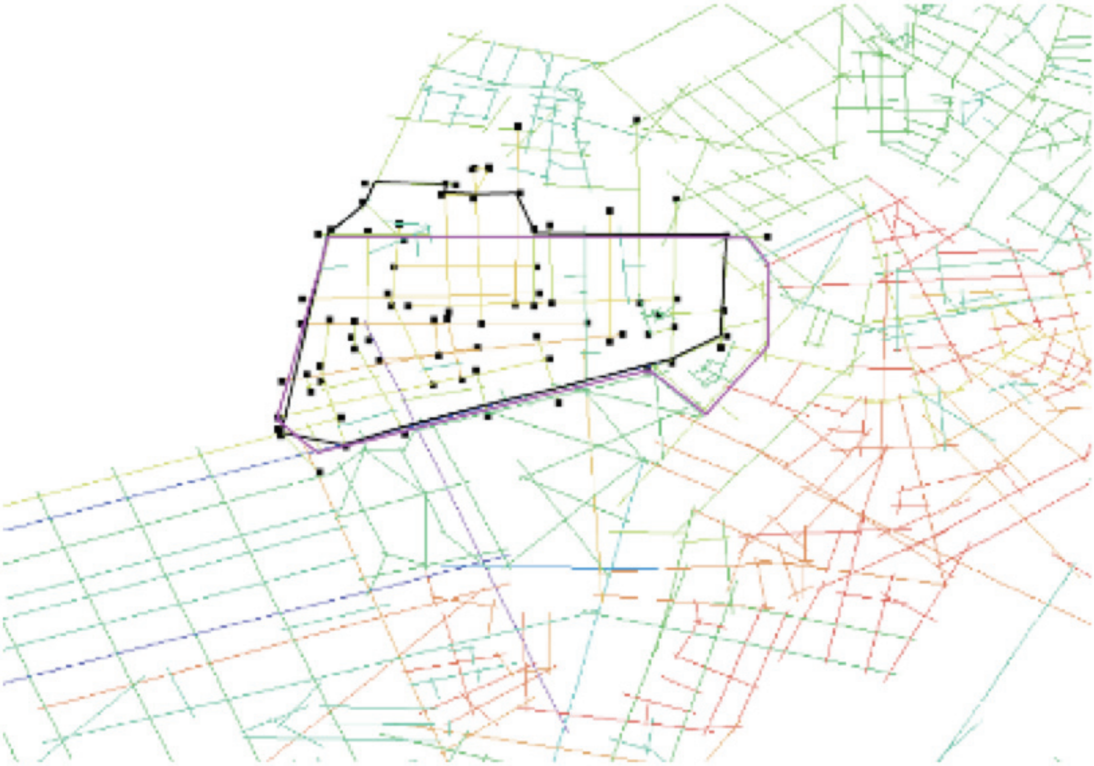


Figure 9.13 Area selected from Pincknet St. and within 3 steps using a 0.1% difference in point synergy R=4, V=90 values. The bold black lines are the convex hull. The purple lines are the Chi-Squared statistical test.

Repeating this experiment for the smaller front-side area (see Fig. 9.11), we find that the Z value for intelligibility V = 90 was –4.237 (Avg for sample = 0.544, stdDev = 0.05, size = 11, avg for population = 0.4803, stdev = 0.1141, population size = 751) and a similar value for synergy Z = –4.662 for vicinity V = 90 (Avg for sample = 0.7012, stdDev = 0428, size = 11, avg for population = 0.641, stdev = 0.1292, population size = 751). Both values are consistent with the assertion that the areas are not random samples of the whole population.

For the area known as the north-side or back-side (see Fig. 9.12), the area given by Lynch only included 4 lines, given the 50% line length rule given above, so the area was expanded to include more of the axial lines that passed into the back-side area zone defined by Lynch. The Z value was 3.996 for intelligibility (Avg for sample = 0.40250, stdDev = 0.0702, size = 13, avg for population = 0.4803, stdev = 0.11412, population size = 751) and for Synergy the value was 1.9351 (Avg for sample = 0.5934, stdDev = 0.0886, size =11, avg for population = 0.6410, stdev = 0.1292, population size = 751). The synergy value gives a greater than 97% probability that the values are the same and the intelligibility value is much higher. Both values are consistent with the assertion that the areas are not random samples of the whole population.

Selected Connection method

A second method is to use a facility in the WebmapAtHome application to select connected lines that have a value similar to that of the source line. Thus, given a central starting line, we can objectively select lines that have approximately the same value. Starting with

Pinknet St. in Beacon Hill, and finding all of the lines within 3 steps that are within 0.1% of the value, we find that the area given by the software is in accord with the bounds provided by Lynch (see Fig. 9.13). With this set of lines, a point field (point cloud) can be formed where the selected lines intersect with each other. Finding the convex hull of this point set gives the black bold lines shown in Fig. 9.13. This polygon should be compared to the original one given by Lynch (drawn as a purple outline).

Given the selected axial lines that are within 3 steps of the starting point, and the axial lines that fall within the bounds of Beacon Hill as identified by Lynch, we can see that we have four types of lines.

- **TRUE, POSITIVES**

  These are selected axial lines that lie within the Beacon hill region.

- **FALSE, POSITIVES**

  These are selected axial lines that do not lie within the Beacon Hill Region.

- **FALSE, NEGATIVES**

  These are axial lines that were not selected but do line within the Beacon Hill Region.

- **TRUE, NEGATIVES**

  These are axial lines that were not selected and lie outside the Beacon Hill Region.

To clarify the statistics, if a selection method managed to perfectly predict the Beacon Hill Region, we would get true-positives and true-negatives, with NO false-positives and NO false negatives. Clearly, a strong mix of true-positives, true-negatives, false-positives and no-false negatives suggests that the method is unable to predict the outcome. Fortunately, this set of outcomes can be tested by a chi-squared test, to come up with a number that suggests the strength of the prediction method. Unlike the previous statistical test, there is no method

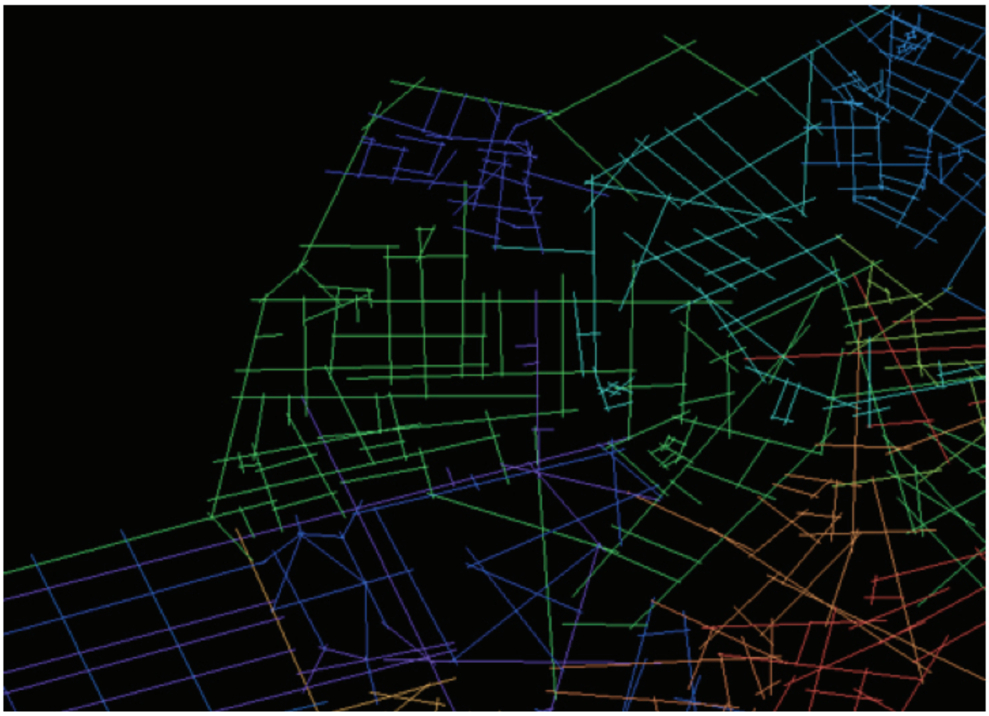


Figure 9.14 Point Synergy Map V180 Radius 4:infinity with 24 Clusters map of Boston after Raford & Hillier. Area in green showing the link-based agglomerative hierarchical clustering zone for Beacon Hill.

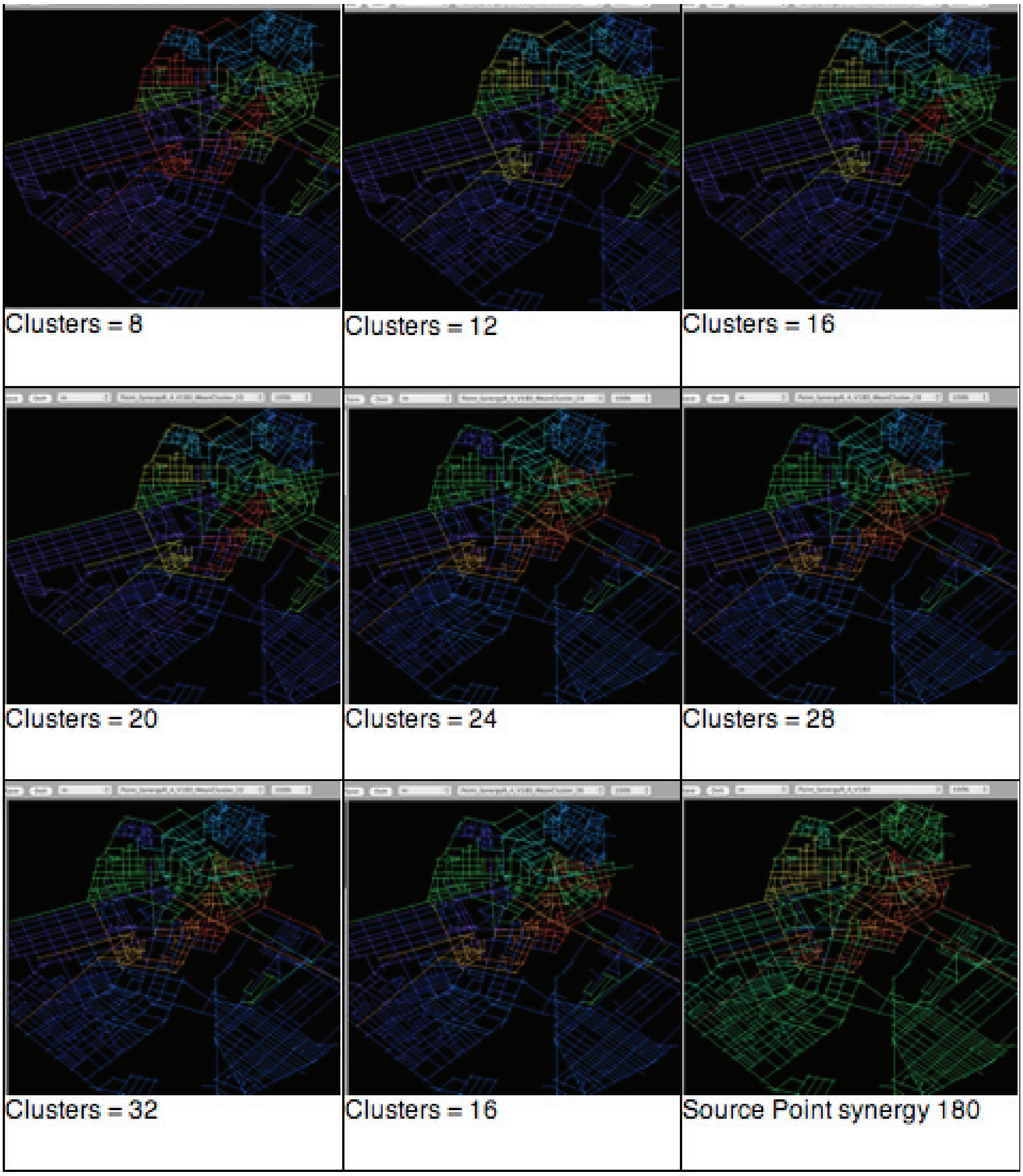


Figure 9.15 Changes in the layout of the neighbourhoods compared to the number of clusters chosen.

to predict the composition of a non-random outcome. One approach to this problem is to compare the outcome for this variable with those of other comparable methods. Thus, the outcome here is not that the method does or does not predict the outcome above a certain level of statistical confidence, but that the method is better than other methods. For non-technical readers, this is like saying that we cannot prove that a drug will cure an ailment since there is no condition where everyone who takes a drug will be cured and everyone who does not take the drug will not be cured. We can only compare a number of drugs and say that this drug is more effective than others. To do this, it is necessary to have a number of comparable methods.

Link based agglomerative hierarchical clustering

One observation about the selection method presented above is that while it is comprehensible, it has problems with both its scope and reproducibility. In the selection method mentioned, the process of selecting the 'origin' line is relatively arbitrary and has a strong outcome on the final zone selected. The choice of radius of three to again be fairly arbitrary. The previous method requires knowlege in advance how many radii will be needed to cover the neighbourhood effectively. To avoid any bias introduced by the origin point or the number of steps needed, a method modified from Romesburg's (Romesburg 2004) agglomerative hierarchical clustering can be used. Agglomerative hierarchical clustering is a method of clustering data, which is grouping data elements into a smaller set of unique subsets. This is typically done to find clusters or groups with natural boundaries between them. Data with two or more numeric attributes are normally used. Agglomerative hierarchical clustering is largely a 'bottom up' method based on the observation that there is a 'distance' between any two data points. For example, if the data element is the x and y position in some kind of Cartesian space, then using a distance metric of Euclidean distance implies looking at the separation between the two points.

$$d = \sqrt{\left(x_1 - x_2\right)^2 + \left(y_1 - y_2\right)^2}$$

Equation 9.1

The agglomerative hierarchical clustering method begins with a set of elements, for example [a][b][c][d][e], and looks for the closest pair of elements, say [b] and [c]. These are then

Method	Chi squared	p-value	True, Positive	False, Positive	False, Negative	True, Negative
Point_Synergy R_4_V180	268.5857	< 2.2e-16	39	39	9	664
EMD=6	57.818	2.88E-14	20	58	24	649
Integration Gradient	25.2597	5.01E-07	24	54	69	604
Orientation	111.9399	< 2.2e-16	31	47	30	643
Random	17.6945	2.59E-05	19	59	57	616
Point_Intel_V180	59.0583	1.53E-14	20	58	24	649

Table 9.2 Results for Chi squared test df=1.

replaced in the set, giving [a][b,c][d][e]. The next closest pair in the resulting set is found and replaced. The meaning of ‘closest’ in the context of group elements can be the average of the values for the attributes used or the minimum or maximum distance between the group’s elements (see Eqn 9.1). The process is then repeated, for example [a][b,c][d][e] might become [a,d][b,c][e], then [a,d][b,c,e] and finally [a,b,c,d,e], that is the root or singular node. The number of nodes can be determined by either setting a limit for the variance of the values within a cluster or finding the number of clusters in advance.

In a general case, the data elements are not attached, as they are in a (axial) graph. The extension used in this thesis is that data elements can only connect if they have a link (intersection/edge) between the nodes in question. In addition, when nodes are merged to form a cluster, the edge set is that of the union of the edges of the components. It is this requirement for connectedness that eliminates other possible clustering methods, such as K-means clustering. Finally, in the search for neighbourhoods, it is necessary to only look at one data value, for example the value of point synergy, point intelligibility, etc. More than one data value could be used, but that would obscure the value of the individual method. This method was implemented in the webmap@home software (version 0.91), which is attached in the accompanying digital media. In this implementation, the number of clusters is required and the repeated merging of nodes continues until the number of nodes is found. In the current implementation, the value (or measure) of each node in a cluster is the average of the node values making up that cluster. When this is found, the neighbourhood region is normally clearly differentiated from the surrounding values and easy to select in a non-arbitrary and repeatable way.

Once the clusters have been formed, as in Fig. 9.14, it is possible to select the appropriate neighbourhood. At this stage, it is a simple process to compare the axial lines within the cluster to those within the boundaries specified and perform the test. One question that arises concerns the determination of the appropriate number of clusters. In the case of axial maps, it was found that once a ‘minimum’ number of axial lines were found, adding more clusters did not make a significant difference to the regions. In Figure 9.15, it can be seen that increasing the number of clusters beyond 22 produces no significant change in the clarity of the neighbourhoods. Thus, it was only important for an approximate number of clusters to be selected. For comparability, it was deemed necessary to expect the different methods to be grouped into the same number of neighbourhoods.

In the case of Beacon Hill, the system was used to produce the table shown below. The calculations and clustering were all performed in Webmap@home and the region comparison was done in the Interstice application. The Interstice application identified the numbers of true positives, false positives, etc., and the final calculation of the chi-squared value was performed in the R statistical language, with the outcomes presented in Table 9.2.

The first item to be noticed is that the random region had the lowest chi-squared value of 17. This is as should be expected; patches are found by aggregating random values, but they are the least strongly related to the actual neighbourhood. All of the methods presented reported higher values than the random value, which suggests that they are all are performing beyond the baseline randomness value. The integration gradient performed poorly at this point, with a value of 25, but since this method was only claimed to be applicable to Dutch cities, its inability to predict an American city does not invalidate the claims made for the method. EMD, with a value of 57, comes next, which suggests that it is performing a reasonable job of computing neighbourhood. Point intelligibility comes next, with a slightly higher value of 59, which suggests that it too does a respectable job of finding neighbourhood.

The Raford and Hillier Orientation method produced a high chi-squared value of 111. However, as will be seen later, this is not a general finding. In this case, the Raford and Hillier paper was written based on the urban structure of Boston, and the axial map used for this zone was that presented by the paper. Therefore, the strong performance of this method should not be surprising. Again, like the intelligibility gradient, the Raford and Hillier method primarily focuses on finding regions within a specific geographic region. Finally, point synergy radius 4 against radius infinity within a vicinity of 180 produced the highest chi-squared value. The large gap between this value and the randomness values suggests that this method is the most accurate method presented in terms of fitting the data. This suggests that in the case of Beacon Hill, of all the measures tested, point synergy was the strongest predictor of the neighbourhood reported by Lynch.

While the results are encouraging and consistent with the hypothesis that point synergy and point intelligibility mappings appear to identify areas of continuous spatial character, the method could be criticised on a number of grounds. First, the sample size of the interviews performed by Lynch was small but, given the necessity of holding a long interview, understandable. Second, the method used to identify the unified bounds was not disclosed by Lynch and the original data is inaccessible. Finally, there is no published street level map that is known to exactly correspond to the space in use at the time of the survey (the city was in the midst of constructional change when the survey was taken). The Raford (Raford 2005; Raford 2005) map is of a later date and large scale modifications to the surrounding urban structure may have occurred in the intervening period. To answer these questions, clearer empirical data is needed.

Direct observation method

For this thesis, a new method of inquiry was developed based on the interview methods mentioned by Taylor (Taylor 1981), Guest (Guest 1984) and by Lee (Lee 1963). The basis of the method was directly asking people to indicate on a map the geographical extent of the area that they considered to be their neighbourhood. Montello(2003) extended this work by asking subjects to draw two bounds (certain within bounds, likely within bounds) and indicate the centre, the objective here was to create a fuzzy probabilistic measure of the region. The hypothesis of this work is that while individuals might exhibit individual variability in their conception of where their neighbourhood was, they would exhibit some inherent area of commonality between their locales. It is known from Guest (Guest 1984) that 25% of the respondents to his interviews thought of neighbourhood with a purely social or a-spatial (a-geographic) view. He also reported that only 30% gave a purely spatial definition. Guest identifies three types of interpretations of neighbourhood. There is the received or institutional definition, the social network neighbourhood and a general geographical area. Guests definitions would clearly influence what kinds of neighbourhoods would be reported. It is worth describing each type in turn so they may be later identified.

Received or institutional definition of neighbourhood

The institutional definition arises from the common observation that area names and identities within metropolitan areas are often attached to major institutions, such as shopping centres and schools, as well as to physical markers, such as parks and streets. These institutions serve as unifying factors in the development of shared symbolic identities. As already noted, others have downplayed the institutional definition for neighbourhoods, but not for communities or local areas (Greer 1962; Hunter 1974). Nevertheless, various researchers have continued to delimit basic 'neighbourhood' units within a metropolis by plotting the distribution of catchment areas for shopping facilities and schools (Warren 1965; Warren 1975). 'And it seems likely that some urbanites will use this definition' (Guest and Lee 1984).

The human social network neighbourhood

This is the social network within some geographic area. McKenzie (McKenzie 1923) noted the existence of personal and general neighbourhoods, where personal neighbourhoods were restricted to those where a social connection existed. This might literally mean that the neighbourhood is composed of one's neighbours, quite possibly sharing the same street.

General geographical area defined in purely spatial terms

We can think of this as the community of the local area. One interesting concept introduced by Guest was that neighbourhood could be considered to be a moving window centred on the respondents. In the paper, it was observed that 14.3% of households identified neighbourhood in terms of a street, block or cul-de-sac (presumably where they lived), and 24.6% responded with a neighbourhood extending one block in each direction. It must be realised that these results were obtained from communities in Seattle, a highly disperse and highly grid-like city. If neighbourhood was used as a definition of place, this would reinforce the Relph notion of place being unattached to a particular location in the metropolitan geography. It is interesting to discern that Guest reports that 'As long as 50 years ago, for example, McClenahan (McClenahan 1929) concluded from a study of Los Angeles residential areas that "…the neighbourhood as a primary group has become obsolete or at any rate is obsolete"' (Guest & Lee (Guest and Lee 1984) quoting McClenahan). The end of neighbourhoods has been reported several times; for example, the geographer Mark Webber (Webber 1963) making observations

Figure 9.16 Example of returned card.

about the rise of transportation and communication technologies, declared that there could be 'community without propinquity'. Equally, Talen (Talen 1999), in a scathing attack on New Urbanism, followed by another on community planning in general (Talen 1999; Talen 2000), observed that,

> *'As long as new urbanists stress the importance of the interrelationship between neighbourhood form, resident interaction, and a sense of community, neighbouring activity (social interaction), engendered by public/private space integration, will have an effect on a broadly defined psychological sense of community and the social claims of new urbanists will be untenable'.*

In a later paper, she goes on to further assert, 'I believe it is essential that planners detach themselves from attempts to engender community via physical means…' (Talen 2000).

Implications for the direct observation method

At the core of this method is the observation that a large number of simple observation points could be used to form a general concept of neighbourhood. This follows the general model of previous space syntax experiments, where large numbers of individuals are observed by counting the rate at which they pass an observer. This should be compared with what might be done in a more psychological study, where individuals would be stopped in the street and asked to map out the route they had taken and would take. This might inform the experimenter about the conceptual process of navigation, but is weakly informative about the impact of the wider urban fabric on route usage.

To achieve a high observation level, a new method based on a postal questionnaire was developed. An A5 postcard was composed with a short introduction, a few simple questions, and a large area devoted to a simple map (see figure 9.15 for an example card). The map was based on an axial map, with annotations indicating the location of some streets (chosen at random with the main integrators included) and the location of transit (underground) stations. It was thought possible that respondents would use the centre of the map as the natural centre of the neighbourhood, thus the map would bias the results. To avoid this the area mapped was larger than that appearing on the card and the area visible on the card was clipped to fit in the card. By offsetting the 'window' on the map randomly, on a batch by batch basis, it was possible to move the centre of the map in an attempt to remove systematic bias.

It was conceivable that respondents would have problems reading a simple map and might well be completely inaccurate about their location and so make errors when identifying the area of their neighbourhood. It was also possible that respondents might mischievously report fictitious neighbourhoods in large enough numbers to affect the statistical validity of the results. To counter this, the cards were marked with an invisible ultraviolet (invisible) ink before posting. This invisible mark, made individually just before delivery, would indicate the street or axial line that the card was delivered to but was not thought accurate enough to identify the individual building and as such not compromise the ethical basis for the experiment. The respondents were asked to identify their street on the map and the location of this mark was compared to the invisible marker, made by the researcher before delivery, which became visible under ultraviolet light. It was found that all of the respondents cards returned correctly identified their street comparing their marks with the ultraviolet 'gold' test. This suggests that the respondents who did return cards were a self selecting group capable of reading the black and white maps provided and had some definite intuition about the geographic area of their neighbourhood. It is not clear whether the ability to fill in the card and identify an area constituted a specific bias. A significant number of inhabitants in the Guest study considered neighbourhood to be a fusion between both social connections and a territorial expanse. Clearly, the cards in this experiment were returned by the 75% of the people who would consider neighbourhood to have some territorial component but the questions about social network where included to help explore the social notions.

Along with the map, the following text was included.

> *Hi. My name is Nick Dalton. I am a researcher at University College London. I am doing research on neighbourhoods and I need your help. I am trying to find out where people feel their neighbourhood is (there is no right or wrong answer).*
>
> *On this map, would you please draw a line around the area you think of as your neighbourhood? By neighbourhood, I simply mean the part of the city where you live.*
>
> *Also would you consider yourself a local? ______ (yes/no)*
>
> *How long have you lived in the neighbourhood? ______*
>
> *Does your neighbourhood have a name? If so what is it?*
>
> *My neighbourhood is called __________________*
>
> *Finally could you draw an arrow pointing to the street you live on?*
>
> *That's it thanks! All you have to do is pop the card back in the post - it's free, no stamp necessary.*

From the Guest definitions it was clearly important from the experimental point of view that participants have some common guidance on what ‘neighbourhood’ meant, yet be permitted all three definitions. It is the evidence of overlap that would be most telling. To this end the definition of neighbourhood introduced by Taylor, ‘By neighbourhood I simply mean the part of the city where you live’, was used.

The reverse of the card held the free post return information. Using the UCL free post system made it possible for people to return cards by placing them directly in the post-box without the need to affix a stamp. This free post system is quite efficient in that the post office only charges for the cards returned. The postage cost was so low when the survey was conducted that UCL did not charge for the cards returned. The basic cost of the survey was that of creating and printing the cards and the time taken to deliver them. The overall return rates were quite high, averaging 11%. All of the residents got essentially the same questions and, by avoiding personal contact, it was felt that any unconscious bias by the interviewer would be avoided. By using this postal method, it was possible to create quite large samples in comparison to personal interview approach. While the direct interview does have the benefit of potential depth the advantages of a broad large sample should not be underestimated.

Fig. 9.16 shows an example card that has been delivered and returned.

Building the consensus boundary

The core of this chapter is the assertion that areas of constant spatial structural properties, such as point synergy and point intelligibility, reflect the beyond the horizon conceptual frameworks that people use, and as such a region of constant point intelligibility or point synergy reflects the region of a natural or potential neighbourhood. To test this hypothesis, it was proposed that we would expect that if there was no relation between space and the reported impressions of neighbourhood it would be impossible to find a statistically significant relationship between the consensus region of neighbourhood and the regions of constant synergy. That is, if Talen is correct, then no relationship between these independent observations of space and neighbourhood could be made. To do this it becomes necessary to combine the polygons representing the boundaries reported by the subjects into a single representative boundary called the consensus boundary.

To find the consensus boundary, it was necessary to find a representative polygon that succinctly summarised the reported polygons of the inhabitants. To do this, an average reported area method was proposed. To begin with a starting point that lay within all the reported polygons was chosen (see Fig. 9.27). From this point, a ray was cast out from that point, noting the distance of intersection from the starting point. Generally, all the reported polygons are functionally convex, making it generally the case that only one point of intersection was found per reported neighbourhood. This method was first introduced by the author in (Dalton 2006).

Given that the points of intersection all reveal distances from the centre, it is possible to apply basic statistical properties, such as mean, max, minimum and standard deviations, to these numbers. The average value would then

	Average	Mode	Plus 1Std dev	Medoid avg	Reduced avg
Point Synergy	**1327.669**	1084.467	969.979	1272.104	1241.423
Point Intelligibility	111.7578	116.1103	**285.7155**	106.4634	161.9375
EMD6	417.288	327.5225	278.4575	**421.6361**	283.3574
Average Integration	**917.4937**	625.1683	821.061	869.0778	777.9547
Orientation	234.2874	254.4244	233.1534	242.7908	**258.7713**
Random	186.5371	253.2058	**350.7994**	165.2021	293.5347

Table 9.3 The chi squared values for the boundaries of Hampstead Garden Suburb.

give the point on the ray that represents the average distance from that point. Repeating this process while rotating the ray around the starting point makes it possible to merge the polygons into an average polygon. The number of rays is arbitrary; Fig. 9.17 shows eight rays, but in practice 360 rays were used. It would also be possible to find both the minimum polygon, effectively the region of intersection of all the reported polygons, and the maximum polygon, effectively the region of union of all the polygons. Geometrically, we can consider that using the maximum boundary is the equivalent of finding the geometric union of all the boundaries and the minimum is the equivalent of finding the intersection of all the boundaries. In effect, the consensus boundary

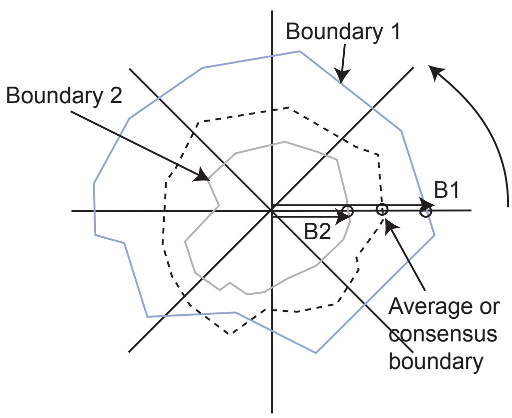


Figure 9.17 Diagram showing the polygon averaging (consensus) method.

is a generalisation of geometric intersection tests.

If we examine Fig. 9.18, it will be noticed that the figure for the ‘average’ boundary does not appear to have a strong match with the boundaries from which it is composed. For example, along the top edge, many boundaries follow a road and the red consensus line appears to move beyond it. In this case, we are seeing the result of having outliers when computing an average. Given that the boundary is just the result of repeatedly finding the average of a group of numbers, it is possible to replace the average with any other method that might be thought suitable. For example, we could use the mode or median rather than the average. A number of alternative averaging mechanisms were experimented with. These methods were:

Average - the point is the simple average of the numbers.

Mode - The numbers were put into one of 10 equally spaced bins (the spacing being 1/11 of the space from min to max) and the centre of the bin with the most elements within that bin range was chosen.

Plus1Std - The average was found along with the standard deviation of all the values. One standard deviation was added to the average

Figure 9.18 Axial map (grey) and average (consensus) neighbourhood in red, mode (yellow) plus standard deviation (green), reduced average (orange), medoid (blue) and source bounds (cyan) for Hampstead Garden Suburb.

in an attempt to add more axial lines to the polygon when there was an uncertainty as to the boundary.

Medoid average - This was used to find the average of the lines and then found the nearest actual value to the average.

Reduced average – The was used in an attempt to remove the outliers by finding the average of the lines and then removing all of the points that lay beyond one standard deviation of the average. The average of all the lines within one standard deviation was re-calculated as the reduced average.

By applying the chi squared test of the number of lines that have been clustered using the altered clustering method mentioned above it is possible to test each consensus polygon against each cluster found (see Table 9.3). While different neighbourhood finding methods produce different chi-squared results, it is possible to find the method that produces the best average for the context. In this case, we can see that the mode mechanism does not produce the highest value in any category. The medoid average only produces one best result and that is for EMD6. Equally, the reduced average only produces the best values for orientation. Both the average and plus 1 standard deviation have two tests they do well on. If we find the average of all the values in each column, we find that the simple average does best

Measure	Intelligibility	Synergy R3	Synergy R4	Synergy R3	Synergy R4
Vicinity Used	90	90	90	180	180
Lines in Inside	168	163	163	163	163
Average inside	0.2163	0.3371	0.26967	0.3052	0.27517
StdDev inside	0.0815	0.09264	0.05604	0.052199	0.05486
Population	2551	2551	2551	2551	2551
Avg Population	0.20099	0.322595369	0.3050	0.2559	0.30076
StdDev Population	0.094	0.1377	0.0522	0.09718	0.04342
Significance	-2.445	-1.9890	7.5388	-12.044	5.95385

Table 9.4 Results for Vicinity = 90, R = 3 for H.G.S.

overall and was therefore chosen as the test method.

Using the consensus polygon, it is then possible to test all of the axial lines within or intersecting the average consensus polygon. If the values within the region are not consistent, we would expect that the values within would be a random sample of the values of those outside. If the converse is true, that the values within are not a random sample, then we could decide that the null hypothesis was not consistent with the data.

The geometric processing was performed in the Interstice application (Dalton, 2004 #595) (code and application in accompanying DVD) and the results are presented in Table 9.4 above. You can see that the significance factors shown are quite high (all greater than the 95% significance level) confidence intervals.

We could attempt to test for spatial auto correlation for the whole system and for the lines within the consensus polygon (Cliff and Ord 1970, 1973, Black 1992, Black & Thomas 1998 within these Pecturs and Thomas 2009) in these systems. Spatial autocorrelation is an attempt to measure to what extent things close to each other are similar in some value. Originally spatial auto-correlation was developed as a response to the problems of looking at a numbers of areas statistically. If for example one is looking at some measure of crime one might consider factors like income and lack of maintenance as possible causes. Yet the question arises: if two areas show similar values might not this be due to the possibility that they are adjacent and are so not statistically independent of each other? To measure this a number of measures were developed such as Morgan's I and Geary's C. Geary's C takes a network of adjacencies and measures the difference between adjacent values. the sum of all these values are normalised producing a value ranging from 0 to 2[2] with 1 representing no spatial correlations (imagine a checkerboard where each value is completely random neighbourhoods) and 0 representing positive spatial correlation and larger than one representing negative spatial correlation[3]. Morgan's I factor works in a similar way except working from 1 to -1 with zero as the mid point of no correlation. Moran's I is a more global measure of spatial auto-correlation whereas Geary's C is more local. Clearly, given that the measurements of

2. Much in the way that persons correlation operates from -1 to 1 with the mid point 0 representing no correlation.
3. Imagine a checkerboard where each value is the exact opposite of its neighbour.

spatial auto-correlation are based on a network of proximity we can create a similar measure of Moran's I and Geary's C using the connectivity graph of an axial map creating what we might call topological auto-correlation.

In the context of an axial map and finding regions which are thought to represent high factors of spatial auto-correlation we would expect that the regions would exhibit higher values of spatial auto-correlation (values closer to 0). Yet this simply informs the observer that the axial lines in the system are grouped. We would expect that the results of Moran's I and Gearey's C for a selected neighbourhood would indicate stronger spatial auto-correlation within a neighbourhood. Yet how do we know in advance what value change (0.00001,0.1 0,2 increase) represents a valid change? As such, while spatial auto-correlation is strongly related to the test, it does not enhance this test and so has not been used.

Conclusion

This chapter has focused on finding a method by which to statistically test if a region finding method like point synergy and point intelligibility matches that found the real world.

The first test an extension of Hillier's test used by Yang and Hillier introduced using Ordinance Survey data. While the OS neighbourhood method is broad and very fast the absence of knowledge of how the neighbourhoods were located and more specifically the necessity to estimate their extents limits this method to a rejection test. While processing this it was found that point synergy performed more accurately than point intelligibility.

A second test and one that will be used later was based on a Z-Test. This test examines an area to see if the values within an area represent a random sample of the values for the entire map. A region of continuity would appear as a statistically unlikely occurrence identified by an extreme value in the z-test. This required the generation of a mechanism to find a single 'consensus' boundary from a number of reported neighbourhood bounds.

The third test, Chi-squared based test using the number of correctly and incorrectly identified values was introduced, which is a stronger comparative test but requires all lines to be reduced the binary condition of being inside or outside the consensus boundary or being inside or side the region of continuous point synergy or point intelligibility. This binary distinction was achieved using a modification of a standard agglomerative clustering method. While the method is reproducible and discursive it does have the problem of being slightly reductionist agains the richness of the map and the notion of neighbourhood boundary.

This chapter has also shown how it is possible to produce a simple method to survey a region for the neighbourhoods within it and coalesce these into a single 'consensus' boundary which can be used by the above mechanisms. The next chapter will apply the latter tests based on actual surveys against a number of regions in order to test the point synergy and point intelligibility measures against reality. .

Key points

This chapter introduces the methodologies used to collect empirical observations of neighbourhoods and to test computed point intelligibility and point synergy against the collected data.

The first wide area approach looked at a number of cities in the UK and tested the regions that the Ordinance Survey labelled as neighbourhoods.

Point Intelligibility and Point Synergy appeared to pass this rejection level test.

The second deep approach looked at the neighbourhoods reported by inhabitants.

This method was successfully piloted upon a region of Boston reported by Lynch.

It was found that changing the radius and vicinity parameters permitted different enclosing super neighbourhoods to be found.

A new observational methodology based on a postal survey was described.

A new method to combine all the reported boundaries into one 'consensus boundary' was presented allowing a statistical comparison to the regions.

A Z-test for the values within and outside the consensus boundary was introduced to test if the values within the boundary was identical to the sample of lines outside the axial map.

A method of link based agglomerative hierarchical clustering of point synergy values was developed allowing a Chi-squared test to be performed to test if the region of constant point intelligibility point synergy mapped onto the consensus boundary reported by the inhabitants.

Chapter 10:
Homogenous Spatial Areas

Summary

In this chapter, the empirical direct observation methodology described in chapter 8 was applied to three areas in London (Clerkenwell, Hampstead Garden Suburb and Brentham Garden Suburb). Each area was given a mail-based survey asking participants to identify their personal neighbourhood. During this data collection it was observed that one area in Clerkenwell was being reported as an embedded neighbourhood (much in the manner of Beacon Hill's north and south sides). The emerging embedded neighbourhood appears to be in the process of place forming (the growth of a commonly used name, such as Amwell Village, is not yet fully established) and is observable in the synergy maps for the larger area. These responses from the sketch collection method were then compared in two ways to the areas suggested by the analytic methods described in the previous chapter. The first Z-test suggested that the regions are non random statistical groups, that is the regions of continuous synergy and intelligibility are not the products of random distributions of values. The second chi-squared test compared the neighbourhoods found by point synergy and point intelligibility with those found by other reported methods, including embeddedness (EMD), local average integration, orientation and a random measure comparison. The result of this comparison is that synergy appears to predict reported neighbourhoods more consistently and accurately than any other method used, including intelligibility, and that all of the methods did generally better than the random measure. This then provides strong support for the place hypothesis, suggesting that neighbourhood place has some embedding in the spatial characteristics of the urban environment.

Introduction

Chapter 9 detailed the methodology with which to collect the empirical data for the inhabitants, synthesise this into a single consensus boundary and then test this boundary against any region finding method such as point synergy and point intelligibility. This chapter follows on from chapter 9 applying the methods to three case studies of Hampstead Garden Suburb (H.G.S), Brentham Garden Suburb (B.G.S) and an area near the city of London known as Clerkenwell. In each case the reported neighbourhood bounds will be compared to a number of methods along with point intelligibility, point synergy, those of an axial version of Embeddedness (EMD) by Yang and Hillier (Yang & Hillier, 2007), Raford & Hiller's orientation method, Read's average integration and a null randomness measure described in chapter 8. This chapter will attempt to answer two questions.

Firstly, do the reported neighbourhoods aggregate to show one similar boundary? If people report unrelated bounds then it could be considered that the notion of neighbourhood is purely an egocentric one and is not ‘shared’ with others. This would reinforce the notion that neighbourhood is a mythical idea, not something that people possess, and as such the idea of neighbourhood as place is purely an extrinsic fiction. If the bounds are similar in some way are people simply reporting back the institutional extent derived from the region where the name (for example Loughton School, Loughton Café, Loughton Library) is used? Are the reported bounds limited to clearly delineated boundaries as suggested by Alexander (Alexander, C., 1977) or can they exist in the mesh of the urban fabric as suggested by Jacobs (Jacobs, J., 1961) - that is, do people report boundaries to their neighbourhood dissipate any clear indicator?

Secondly, if reported neighbourhoods aggregate to show one similar boundary, does this boundary relate to the spatial structure of space? If space is unrelated or weakly related to neighbourhood then the expectation would be to find no or very weak connections. Finally from the selection of comparable spatial neighbourhood finding mechanisms does intelligibility or synergy perform more accurately than other methods? If it does not then what does this imply for Hillier’s work (Hillier 1988, Hillier 1996) on the role of synergy in named areas?

We saw from the previous chapter that, while the test is not fully conclusive, the identification of named areas from the Ordnance Survey maps that we might expect that synergy would be a stronger contender for the ability to describe the natural bounds for an area.

This chapter will continue by introducing and analysing each area in turn. Each area will be assessed and then the final overall conclusions from this data will be drawn in the next chapter.

Hampstead Garden Suburb

Three sample test areas are presented. The first is Hampstead Garden Suburb, which is a planned suburb in London. The axial map of the area is presented in Fig. 10.1, with the bounds of the original suburb marked with a bold black line. The axial map was taken from a larger axial map of London developed and donated for academic research by Space Syntax Ltd. The suburb was founded in 1907 by Henrietta Barnett (1851-1936), with a number of social aims leading to an attempt to create a diversity of classes and income groups. The master plan was created by Barry Parker(1867-1947) and Sir Raymond Unwin (1863–1940), reflecting the ideas of Ebenezer Howard’s Garden Cities movement (Howard 1898). The area was designated as a conservation area in 1968, implying little change in urban structure from that date. Fig. 10.2 shows the development of the suburb. The railway expansion of the then new Golders Green station (marked with a yellow triangle on the map) prompted Henrietta Barnet to want to preserve the character of Hampstead Heath from ruthless developers. Fig. 10.2 shows the historical development on a 1916–1920 map; (b) shows the pre-first world war ‘old’ suburb. The later development by Unwin and Parker suffered from the influence of Camilo Sitte’s analysis of European cities (especially German medieval cities), focusing on visual diversity

Figure 10.1 Axial map of Hampstead Garden Suburb (in bold outline) within larger context map.

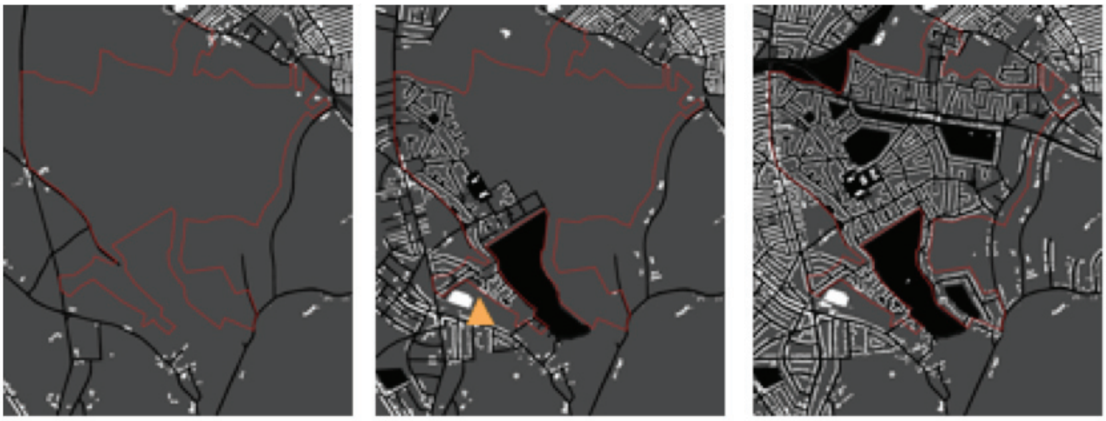


Figure 10.2 Historical map, Hampstead Garden Suburb (from Miranda, Chan et al., 2007), showing growth (a) 1849-1889, (b) 1916-1920, (c) 1935.

within the suburb (see Miranda, Chan et al. 2007 for more info). Hampstead Garden was also designed with a number of symbolic 'gates' into and out of the suburb. Post-war construction saw a shift in methodology, leading to Hampstead Garden Suburb being portioned into two distinct neighbourhoods: the pre-war "old" suburb, with the NW11 postcode, and the newer post-first world war north Easton suburb, with the N2 postcode. Kim (Kim, Y.O., 1999) while studying Hampstead Garden Suburb found from the results of sketch mapping and from questionnaires taken from the inhabitants and that the suburb was perceived by its inhabitants as being divided into halves (the newer and the older areas). The older half he found was more intelligible and the newer half was less so. This he found was reflected in response and by the correlation with observed pedestrian movement and the way that residents understood their neighbourhood

The axial map (Fig. 10.1) was processed with WebmapAtHome, producing the integration map seen in Fig. 10.3.

From Fig. 10.1, we can see that the area of Hampstead Garden Suburb is an enclave adjacent to Finchley Road to the West (marked in white on the map). The neighbourhood is transected by the A1 (Falloden Way leading to Lyttelton Rd leading to Archway Rd) to the north, leaving a small section of the original project to the north of this Rd. Examining the choice map in Fig. 10.4, we can see that both Finchley Rd, North End Rd (at the bottom of the image), the North circular (diagonal line to the north) and the A1 leading to Archway all are prominent in the choice measure, thus showing the supergrid (or the vehicular network) of London. This could be interpreted as a contradiction of the Peponis view that values of high choice define the boundaries of neighbourhoods, since Falloden Way/Lyttelton Rd/A1, clearly pass through the neighbourhood. In the defence of Peponis, the bounds indicated show the original designed institutional bounds of the neighbourhood, rather than the natural neighbourhood, which will be presented later.

As mentioned Kim (Kim, Y.O., 1999) and Kim & Penn (Kim,Penn 2007) also chose this area for study using space syntax. Kim's thesis work was the study of the relationship between cognitive maps and global spatial structure based on data from an empirical process of collecting residents sketch maps. Kim's findings

Figure 10.3 Axial map of Hampstead Garden Suburb coloured by global integration.

Figure 10.4 Axial map of Hampstead Garden Suburb visualising the choice measure.

included a positive relationship between the spatial configuration in the real world and its representations in sketch maps. Examining sketch maps showed that residents tended to simplify and make maps more intelligible than the real world suggesting that intelligibility was an important spatial property from a cognitive point of view. Kim and Penn comment that local integration shows the best relationships with sketch map (and so cognitive map) variables such as the frequency with which features represented. The general conclusion is that Hampstead Garden Suburb is a well structured and is highly navigable (intelligible) by its local residents.

Fig. 10.5 shows the axial angular global integration map of Hampstead Garden Suburb. See (Dalton 2001) for a detailed explanation of the axial angular integration. This map is similar in many ways to global integration and reinforces the local importance of Finchley Rd, the A1 and the north circular.

Fig. 10.6 shows an axial map of Hampstead Garden Suburb showing the local radius 3 measure of integration. This confirms that Finchley Rd and Falloden Way exist as the main local shopping and service streets.

Fig. 10.7 shows the large scale distribution of the Read based average radius 3 integration measure. It would be difficult to suggest that this is consistent with mapping neighbourhood areas as the kinds of patches which would indicate areas do not appear to be emerging.

Point intelligibility

The axial map was a processed vicinity and it was found that the reciprocal of vicinity = 20 correlated well with radius 3 integration ($r2$ = 0.8997). This measure was used to produce the point intelligibility and point synergy axial maps presented in figs 10.8 and 10.9.

Finally, the synergy values were expanded as a check to R = 4 and V = 180.

Fig. 10.10 appears to provide a number of boundaries, although Hampstead Garden Suburb appears to be partly fragmented. But, it is partly fragmented by the primary high choice route (the A1) and with an area that is part of the southern end of the pre-war N11, which is more consistent with the area around Golders Green tube station.

Fig.10.11, the map of Hampstead Garden Suburb from point synergy with radius 4 and a vicinity of 180, gives the lower southern half of the pre-war N11 area of Hampstead Garden Suburb as a region of light blue, which is generally continuous with the closer Golders Green area. The right side (east) of the Northern zone (marked on the map in light green) also continues to fill in the gap in the original Hampstead Garden Suburb plan. It is interesting to observe that the eastern boundary is in striking accord with the institutional bounds.

Survey returns

Three hundred cards were distributed to the suburb within two zones, one on the borders of the first pre-war phase and the second near the middle of the neighbourhood. Thirty-three cards were returned and the information that they contained is presented in Table 10.1, with the bounds appearing in Fig. 10.12. Of those returned, 28 (88%) had the correct institutional name for the area (Hampstead Garden Suburb), three failed to return a name and one had the wrong name. This high rate of 88%

Figure 10.5 Axial Angular global integration of Hampstead Garden Suburb.

Figure 10.6 Axial map of Hampstead Garden Suburb visualising the local Radius 3 integration measure.

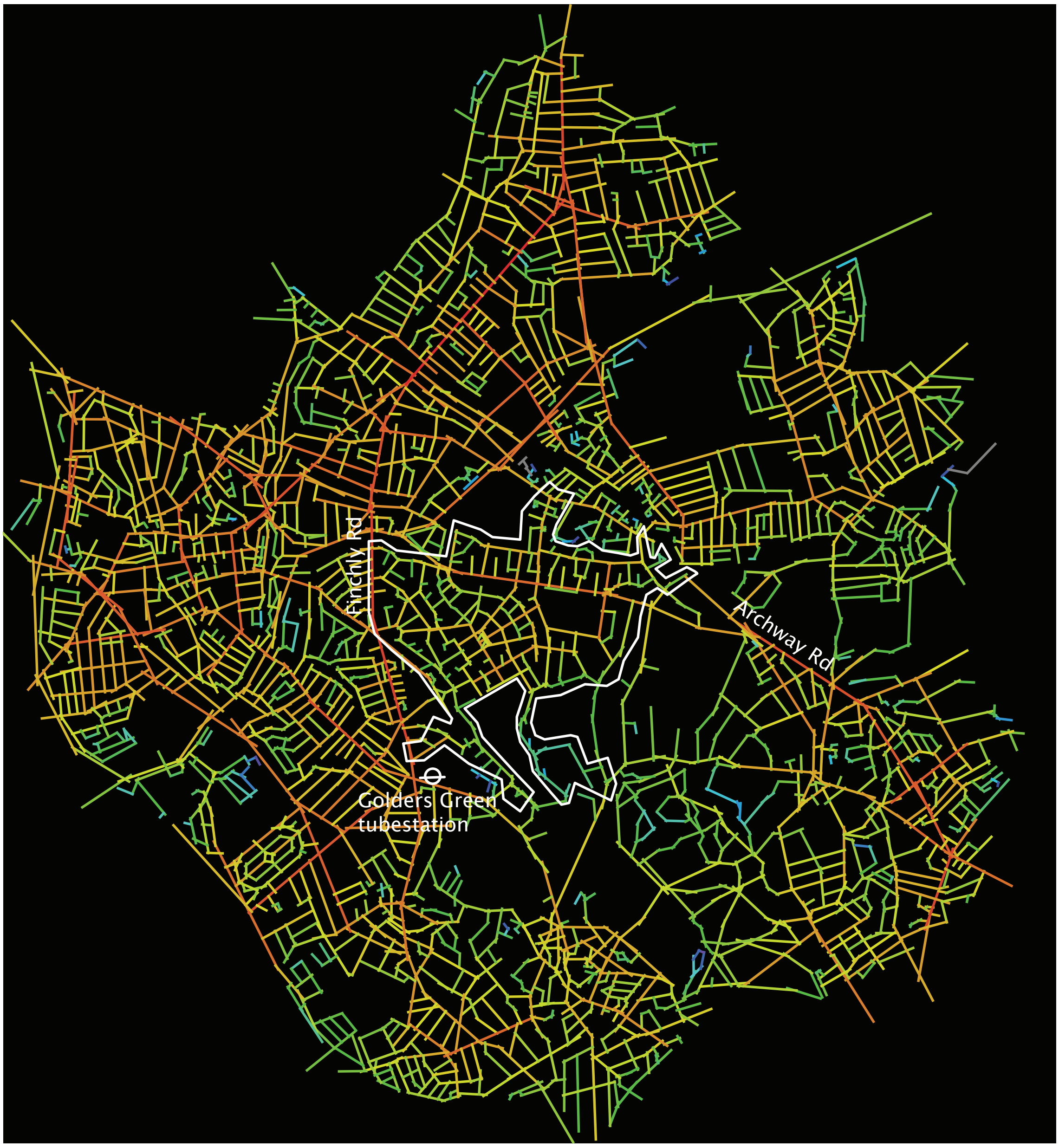


Figure 10.7 Axial map of Hampstead Garden Suburb visualising the average radius 3 integration measure.

Figure 10.8 Axial map of Hampstead Garden Suburb visualising the point intelligibility (v=20) measure.

Figure 10.9 Axial map of Hampstead Garden Suburb visualising the point synergy (v=20) measure.

Figure 10.10 Axial map of Hampstead Garden Suburb visualising the point synergy measure for V=180, R=4.

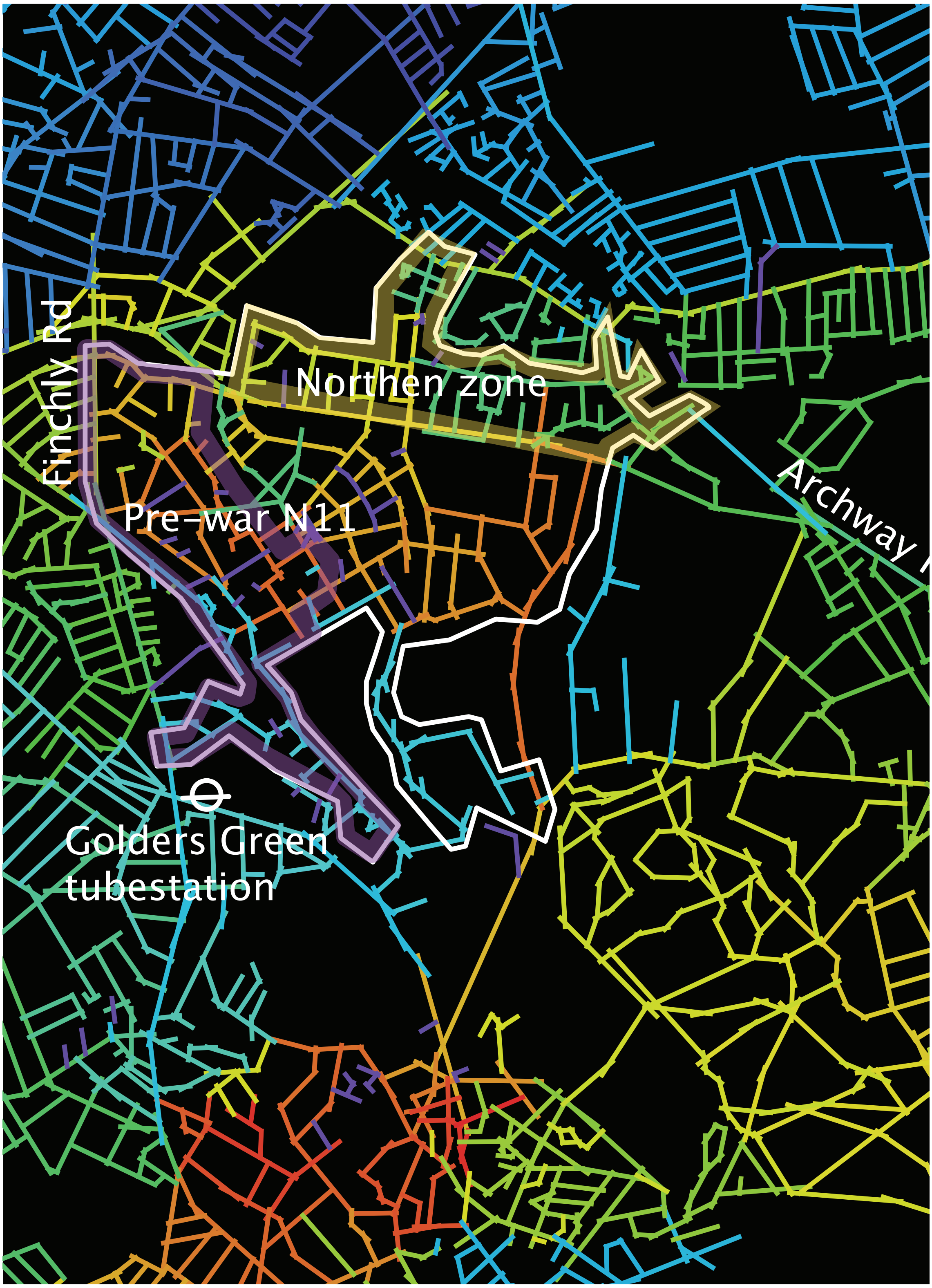


Figure 10.11 Hampstead Garden Suburb by point synergy V=180, R=4.

CardID	Households	Residence	Name	Ninc	Phase
4193		31	Hampstead Garden Suburb		2
4189	30	20	Hampstead Garden Suburb		2
4191	10	27	Danni		2
4192	60	30	Hampstead Garden Suburb	1	2
4194	25	22	Hampstead Garden Suburb		2
5000	10	18	The suburb		2
5001	40	28	Hampstead Garden Suburb		2
4190	15	12	Hampstead Garden Suburb	0	1
5002	22	16	Hampstead Garden Suburb		2
5003	20	42	Hampstead Garden Suburb		1
6000	12	24	Hampstead Garden Suburb	1	1
6001	25	13	Hampstead Garden Suburb	1	2
6002	25	3	Hampstead Garden Suburb		2
6003	8	13		0	1
6004	30	35	Hampstead Garden Suburb		2
6005	28	16	The suburb		2
6018	4		Not given		2
6101	9	5	Hampstead Garden Suburb	0	2
6010	30	35	Hampstead Garden Suburb	0	2
6011	3	7	not given	0	2
6009	30	11	Hampstead Garden Suburb	1	2
4194	25	22	Hampstead Garden Suburb(south side)	0	2
6102	20	20	Hampstead Garden Suburb	0	2
6103	40	36	Hampstead Garden Suburb	1	1
6104	30	40	the Garden Suburb	1	1
6105	20	5	Hampstead Garden Suburb	0	2
4193	loads	31	Hampstead Garden Suburb	0	2
6006	12.5	12	Hampstead Garden Suburb	0	2
6007	20	20	the suburb	0	2
6008	20	35	Hampstead Garden Suburb	0	1
7000	10	22	Hampstead Garden Suburb	0	2
7001	200	45	Golders Green	0	1
7002	50	16	Hampstead Garden Suburb	0	1

Table 10.1 Hampstead Garden Suburb respondents.

demonstrates that there may be a high degree of institutional or received knowledge, or possibly social linkage, within the community. On average, the respondents had lived there for 22.25 years (median 21, std deviation of 11.39 years, min 3 years, max 45 years), showing a strong degree of inhabitation and, as suggested by Taylor (Taylor, Gottfredson et al. 1984), a marker for a high degree of community. The respondents reported knowing an average of 2~~8.~~5 other households (median 22, Std Deviation of 34.3, minimum of 3, and maximum of 200), suggesting a strong degree of social interaction between residents.

Each card returned was catalogued and the bounds of the sketch map were entered into a GIS system and given an arbitrary colour. This map is presented below in Fig. 10.12. While the

Figure 10.12 Union of bounds returned by respondents.

sum of all the returns is apparently confusing, we can make a number of interesting observations.

First, respondents 4191, 7000, 6003 and 6018 were the only ones not to include the central square in their neighbourhoods (see fig 10.13). Respondent 4191 also had one of the smallest known lists of local households (10, smallest 4) and Respondent 6018 reported the smallest number of years present and also wrote 'not a friendly area'. Neither respondent (4191 and 6018) gave the well-known institutional name for the neighbourhood (Hampstead Garden Suburb), which reinforces the study made by Taylor (Taylor, Gottfredson et al. 1984) on factors for naming. We could regard these as giving the personal definition of neighbourhood as literally 'where my neighbours live'.

None of the respondents gave the exact institutional bounds of both the original suburb design and the conservation area, and thus were not fully aware of or reported the institutional bounds. It is interesting to observe that only eight respondents included what might be termed the northern zone (see Fig. 10.14) in their definition of neighbourhood, and when they did, six included all or part of the area to the north of the zone. This observation is interesting for a number of reasons. First, the majority of the respondents stopped their

Figure 10.13 Respondents 4191, 7000, 6003 and 6018.

Figure 10.14 Northern zone respondents 6000, 6103, 4189, 4193, 4192, and 6104.

neighbourhoods at the A1, giving evidence to the Peponis view of strong choice lines being the edges of neighbourhoods. Finally, the buildings in this area are of the same type and general design, by the same architect and same building corporation and builders, and have the same kinds of special restrictions, such as forbidding walls and insisting that separations be made with hedges. As such, this weakens what might be termed the case for Montello (Montello 2007) of the primacy of visual character of neighbourhood, and as such could be inferred to be implicit support for a more spatial definition of neighbourhood. Viewing the Point Synergy Map, we observe that the zone of point synergy V = 180, Radius 4 begins at the A1 and extends beyond the institutional bounds to the north, and that it is this zone that three or four of the respondents identified.

Of the cards delivered to the phase one (pre-war) area near the Golders Green station, we see a range of responses. Respondent 5001 gives a personal neighbourhood (neighbourhood is where my neighbours live). Three respondents, 6000, 6103, 6008, 5003 give the common HAMPSTEAD GARDEN SUBURB response, but cards 7002, 7001, and 4190 give a region separate from the main consensus body. Referring to Fig. 10.15, we see that the areas they report

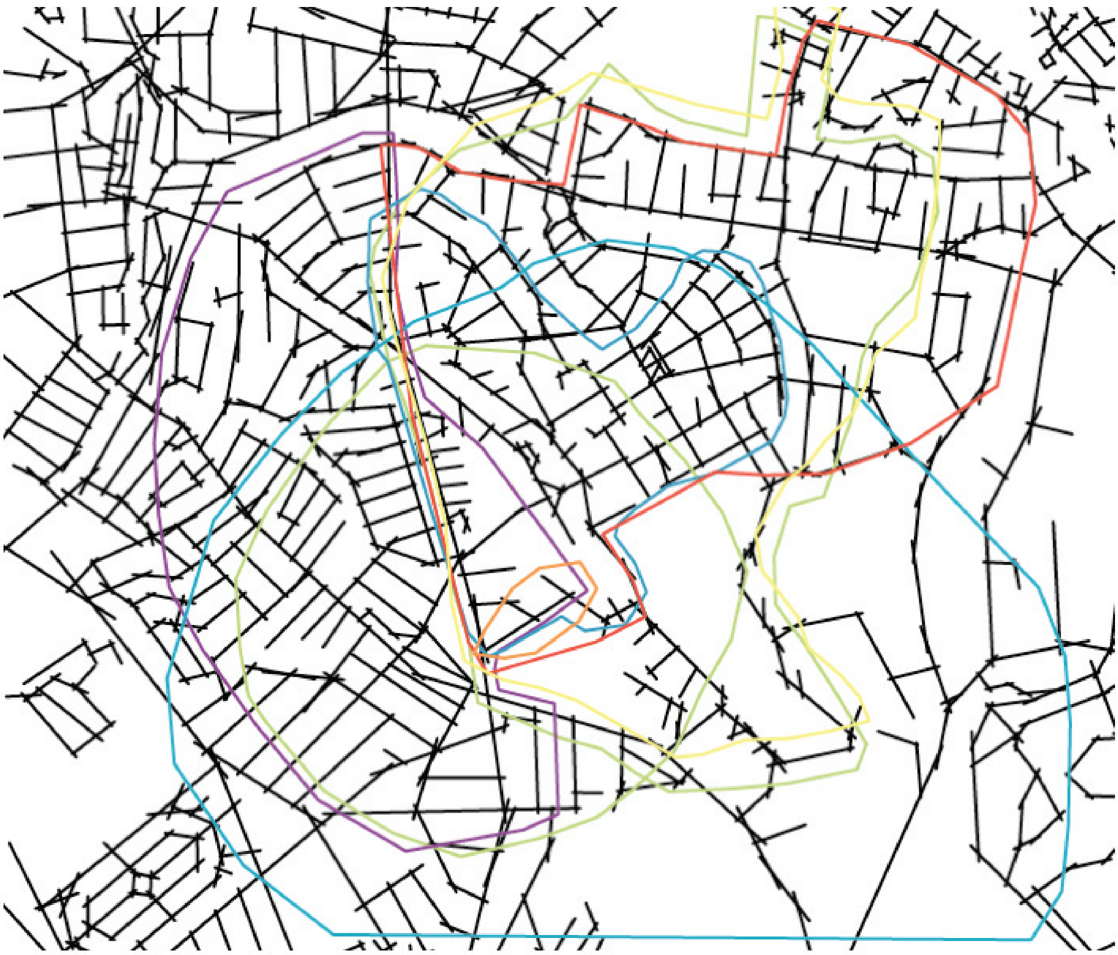


Figure 10.15 Bounds for those reporting neighbourhoods living in the phase one (pre-war) area.

Figure 10.16 Central area.

cover more than the Golders Green area (light blue coloured lines in the figure). This could be rationalised in the following way. Those living in the southern pre-war phase, with the post-code of N11, might well consider themselves members of Hampstead Garden Suburb – using received and possibly social mechanisms, even though the natural space suggests that they are in an unnamed area with its heart at the Golders Green tube station. The maps are thus reflecting this conflict between received neighbourhood (Hampstead Garden Suburb) and the neighbourhood of spatial continuity. This is also confused by the postcode being part of the received neighbourhood. It is interesting to note that of those living there, only 6 report the area that the respondents marked as their street as being in the HAMPSTEAD GARDEN SUBURB neighbourhood.

Finally, all but four respondents (including the two personal neighbourhoods) included all of the central area that is identified as a near constant zone of constant synergy in the computations. It is interesting that while no two responses were identical, they all broadly showed a rough consensus of where the neighbourhood is.

We can interpret from the table that smaller vicinity values do not create an accurate picture for the whole of Hampstead Garden Suburb. A larger vicinity value (180) produces a more consistent picture (see figure 10.17). This is theorised to be a product of the larger physical dimensions of Hampstead Garden Suburb. This area is certainly larger than one might

Figure 10.17 Screen shot from Interstice showing axial lines in red intersecting and within the average (consensus) neighbourhood with the other lines displaying R=4, V=180 synergy.

typically expect for a neighbourhood, and as suggested, is a product of the original construction project elements of the received and institutional notions of neighbourhood. This reinforces the visual interpretation that the values observed are in fact forming one consistent zone within the average polygon derived from the residents. Thus, we can theorise that while the original and institutional bounds of the area have been eroded by the configuration of the site, the original large scale neighbourhood concept has remained largely intact. Although not reported for space reasons in Table 10.2, the significant factor for intelligibility is –4.8385, a weaker value (despite there being less than a 0.1% likelihood of it being a random occurrence) suggesting that intelligibility is performing less well against synergy.

Finally, it should be noted that this data is not consistent with the assertion that it is impossible to derive social concepts, like neighbourhood boundaries, from a purely objective spatial network.

Chi-Squared statistical test for Link based agglomerative hierarchical clustering

The method mentioned above of finding 24 clusters of near continuous values was repeated and the values, including the chi-squared values, are presented in table 10.3 below. In this case the simple average consensus boundary method (as previously described) was used.

The results presented in Table 10.3 begin with point intelligibility with a vicinity of 180 as the lowest chi-squared value. This suggests that in the context of Hampstead Garden Suburb, the zone found by the linked based agglomerative hierarchical clustering was actually worse than that found for the random value (186.5). This suggests that in this case, point intelligibility was not identifying the neighbourhood

Measure	Intelligibility	Synergy R3	Synergy R4	Synergy R3	Synergy R4
Vicinity Used	90	90	90	180	180
Lines in Inside	168	163	163	163	163
Average inside	0.2163	0.3371	0.26967	0.3052	0.27517
StdDev inside	0.0815	0.09264	0.05604	0.052199	0.05486
Population	2551	2551	2551	2551	2551
Avg Population	0.20099	0.322595369	0.3050	0.2559	0.30076
StdDev Population	0.094	0.1377	0.0522	0.09718	0.04342
Significance	-2.445	-1.9890	7.5388	-12.044	5.95385

Table 10.2 Results for Vicinity = 90, R = 3 for H.G.S.

correctly. The Raford and Hillier axial orientation method functioned slightly better than randomness, and might be concluded to be like point intelligibility, only functioning close to the bounds of randomness. EMD at radius 6 fared far better, being more than twice the value of the randomness measure, which suggests that this method does identify boundaries with some reasonable degree of accuracy. Finally, point synergy radius 4, using a large vicinity of 180, performs very well in this case, with a value more than twice as high as EMD and more than seven times that of the pure randomness measure. This suggests that point synergy gives a clearer picture of neighbourhood than any of the other methods.

For Hampstead Garden Suburb, it looks as if point synergy is giving the best reasonable picture as to the extent of the neighbourhood.

Brentham Garden Suburb

The work on H. G. S. could be criticised by observing that the data was also partly consistent with the high choice of boundary neighbourhood introduced by Peponis. The next data is significant in that it presents and area that is free of strong local choice barriers.

Brentham Garden Suburb (B. G. S.) is another suburb of London near Pitshanger in Ealing (see Figure 10.18 for axial map of surrounding area) has a large number of similarities with Hampstead Garden Suburb. Both were largely

Method	Chi squared	p-value	True, Positive	False, Positive	False, Negative	True, Negative
Point_ Synergy R_4_V180	1327.669	< 2.2e-16	103	52	22	2374
Point_Intel_ V180	111.7578	< 2.2e-16	39	116	107	2289
EMD=6	417.288	< 2.2e-16	96	59	192	2204
Average Integration	917.4937	< 2.2e-16	108	47	82	2314
Orientation	234.2874	<2.2E-16	55	100	105	2291
Random	186.5371	< 2.2e-16	80	75	282	2114

Table 10.3 Results of testing the L.A.H.C. axial sets against the consensus boundary for H.G.S.

Figure 10.18 Axial map showing the context with Brentham Garden Suburb in the centre in red.

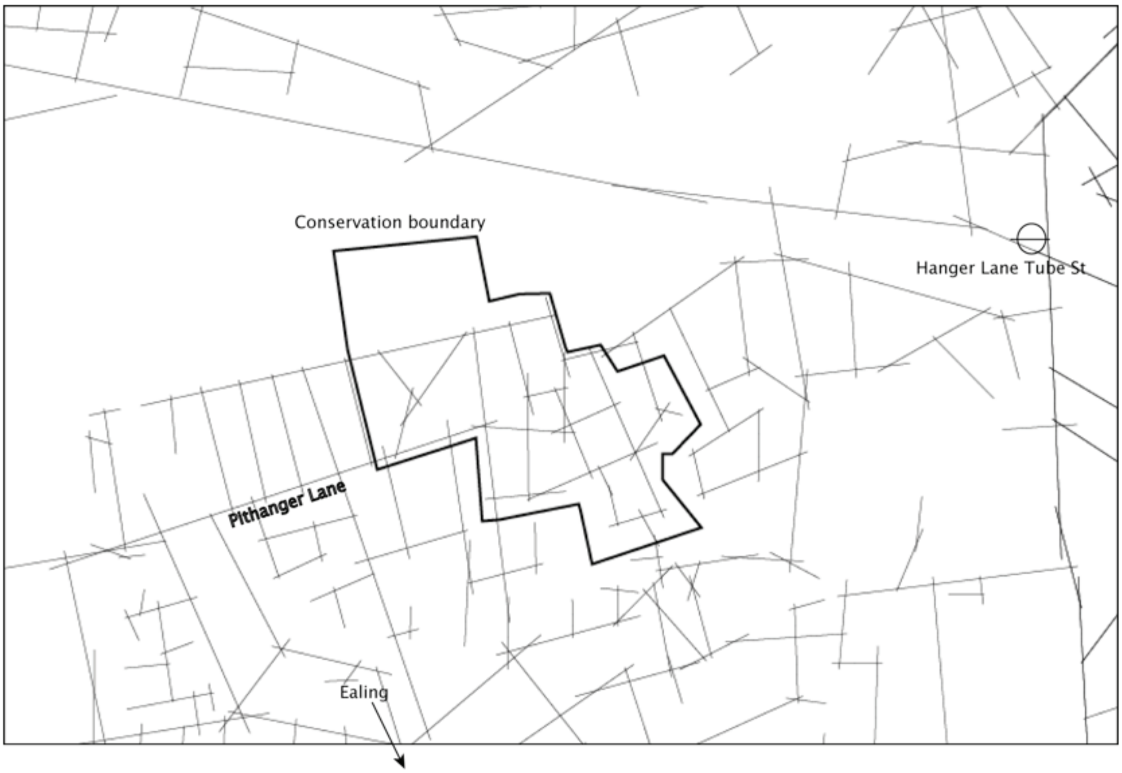


Figure 10.19 Centre of axial map of Brentham Garden Suburb showing conservation boundary.

designed by Barry Parker and Raymond Unwin. Brentham Garden Suburb is also now defined by a conservation boundary designated in 1969. The area also emerged in three phases, the first was 1901–1906, the second was 1907–1911 led by Parker and Unwin, with the houses designed by Person and Sutcliffe and the third was 1911–1920, where Sutcliffe replaced Person as the suburb's architect. A later development created a link to the newly built (and closer) Hanger Lane station in 1935 (Reid 2000; Society 2006).

The project concept did not emerge from the initial desire to have a 'garden suburb', but was a pioneering project of a co-partnership housing movement, a concept linked with it. It was Parker and Unwin who took over the design of the project, after some initial construction had been done in the Edwardian style, and worked with the conscious desire to create a 'garden suburb'. Much of this work was done at the same time as the design of Hampstead Garden Suburb, leading to some stylistic similarities. Both projects, for example, have a common Tenants Association building and recreation facilities. There are differences; first the Brentham Garden Suburb extends over a much smaller area than Hampstead Garden Suburb, and this area was not built with any strong markers, such as Hampstead Garden's symbolic 'gates'. Later development extended the project, rather than isolating it.

Like Hampstead Garden Suburb, the axial map of Brentham Garden Suburb was derived from the larger M25 axial map donated by the space syntax lab. A generous surrounding area was used and the map was corrected after both a site visit and the use of local area mapping

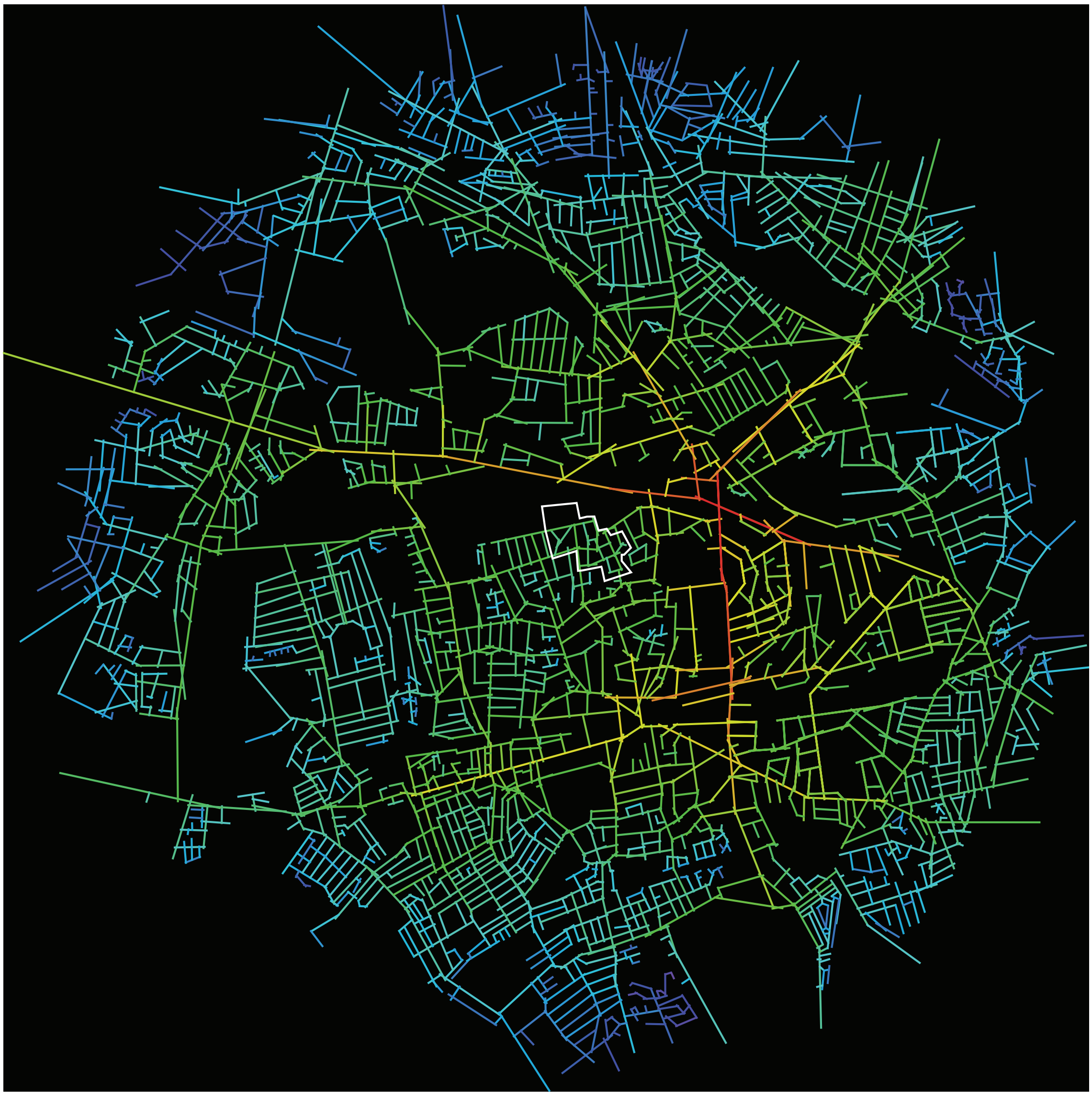


Figure 10.20 Axial map of Brentham Garden Suburb coloured by global integration.

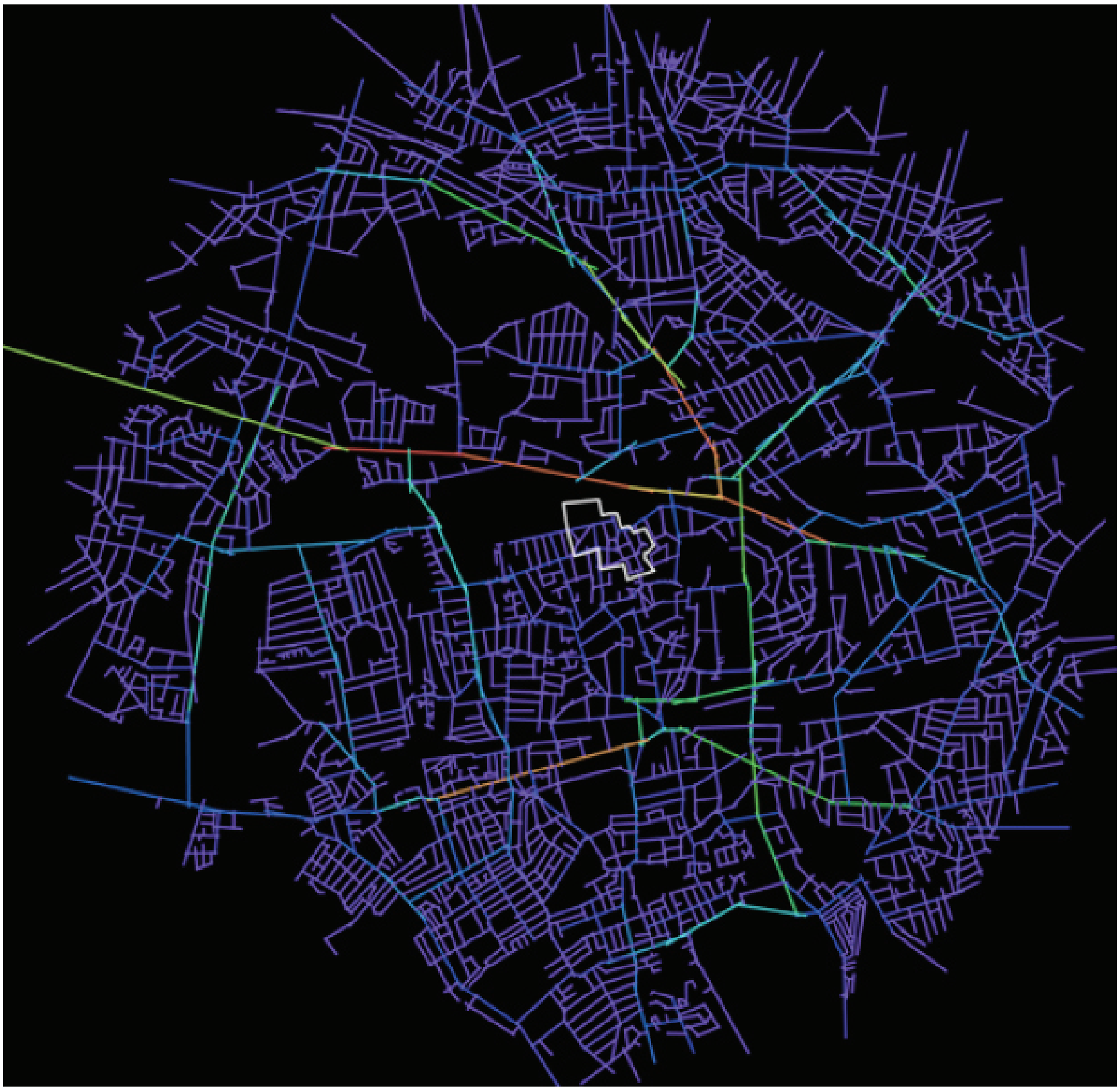


Figure 10.21 B.G.S. and surrounding area coloured by global choice.

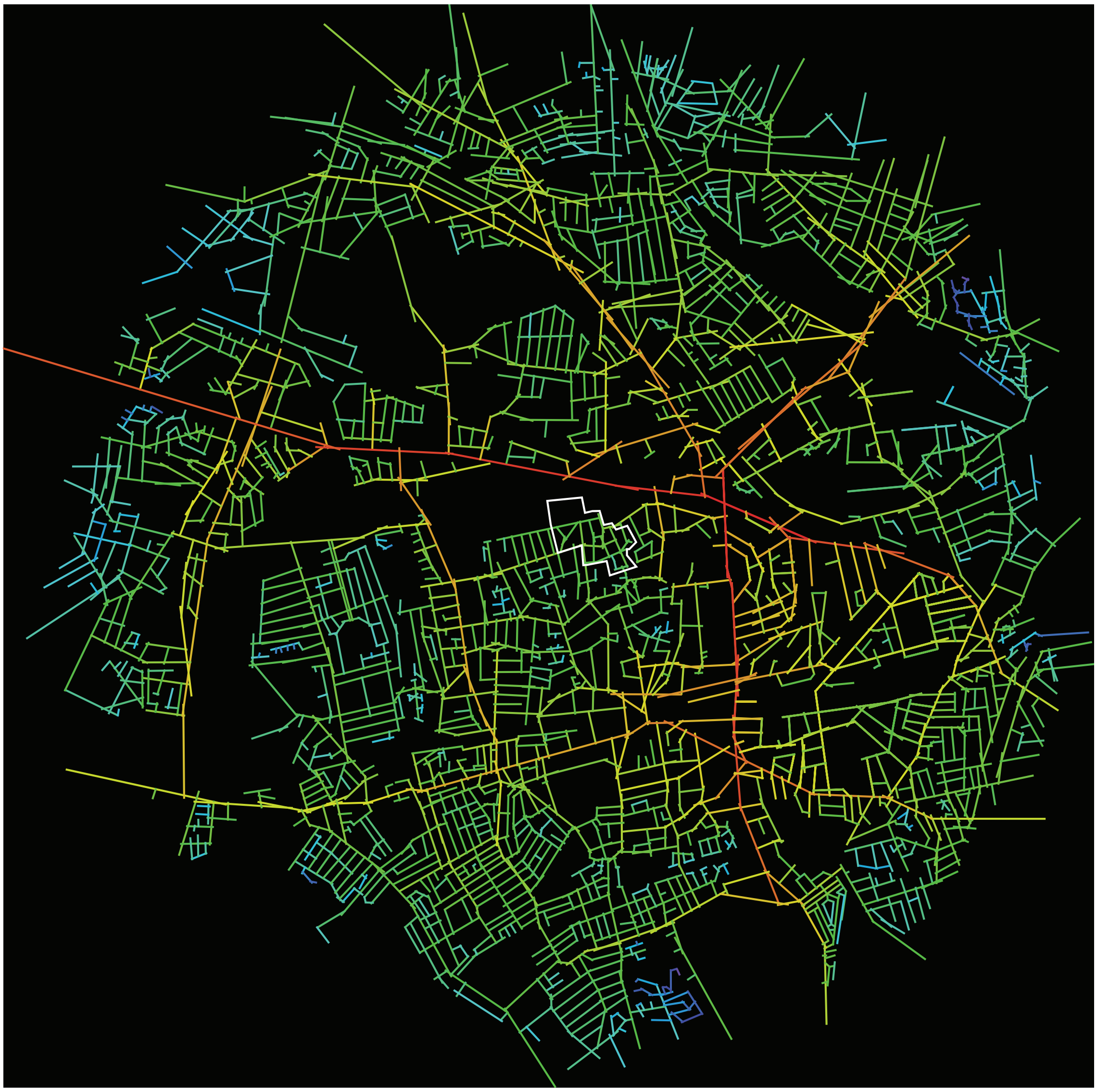


Figure 10.22 Axial map of Brentham Garden Suburb and surrounding area coloured by global angular axial integration.

Figure 10.23 Axial map of Brentham Garden Suburb coloured by the Radius 3 integration measure.

(from Google maps) to checked the accuracy of of the spatial representation.

Fig. 10.19 shows the bounds of the original 1969 conservation area, which is practically identical to the original garden suburb bounds. It should be noted that the original construction was focused on the then existing town of Ealing to the south as the primary focus of transport, with the Hanger Lane tube station being built later in the 1930s. Fig. 10.20 and 10.22 show the integration and angular integration patterns for the whole axial map, showing the large scale structure of space and giving a strong indication of movement patterns.

Fig. 10.21 shows the area surrounding the site coloured by the global choice measure. As we can see, this area is not bounded by any close lines of high choice value, leading to this data being set free from the local influence of high choice 'super-grid' barriers. The bounds in this case are more likely to be influenced by historic processes, spatial structures and perceptual limits, rather than the impact of the super-grid, as suggested by Peponis.

The axial map of Brentham Garden Suburb coloured by integration radius 3 (Fig. 10.23 above) shows that Pitshanger Lane has a large integration radius 3 value, suggesting that it is a local integrator, a fact confirmed by a site visit. The left portion of the line is a local shopping street.

Examining the average radius 3 area, we see that the area north of Ealing emerges as one nearly constant area, with the zone between Park Royal, North Ealing, North Acton, Acton and Ealing common having a distinctive colouration. However, this does not reflect any strongly named area.

We can see from Fig. 10.25, the map of point intelligibility vicinity = 90, that the area around Pitshanger Lane emerges as a distinctive blue zone, as does an area of a interwar neighbourhood between Park Royal and North Ealing.

From Fig. 10.26, we can see that the point synergy (v = 90) appears to divide the project into two zones, the first (blue to the left) being centred around Pitshanger Lane and the second portion (green to the right) covering the third stage of the project, centred on Brentham Way.

Increasing the vicinity value to V = 180 does not appear to 'merge' the zones, although it does reduce the differences between them.

Increasing the synergy radius to 4 and using a larger vicinity value of 180, we see that the area now includes most of the conservation area, but it also includes a considerable area to the south (red in Fig. 10.28). Clearly, from this data it should be apparent that any change in parameters is unlikely to find a single zone approximating Brentham Garden Suburb's official bounds.

Survey returns

Three hundred cards were delivered to the area over a one day period, with the principal

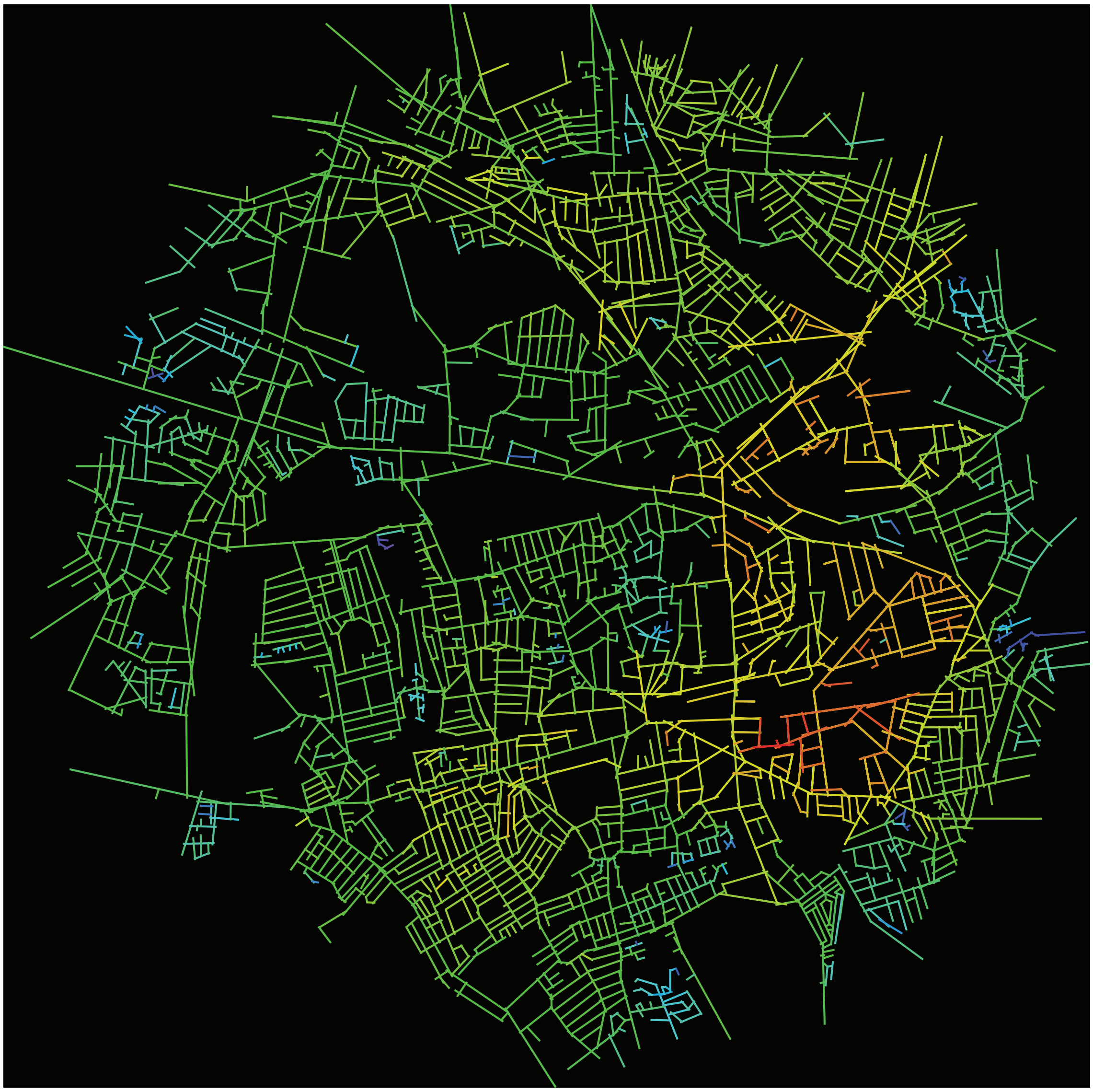


Figure 10.24 Local Radius 3 average of Radius 3 integration.

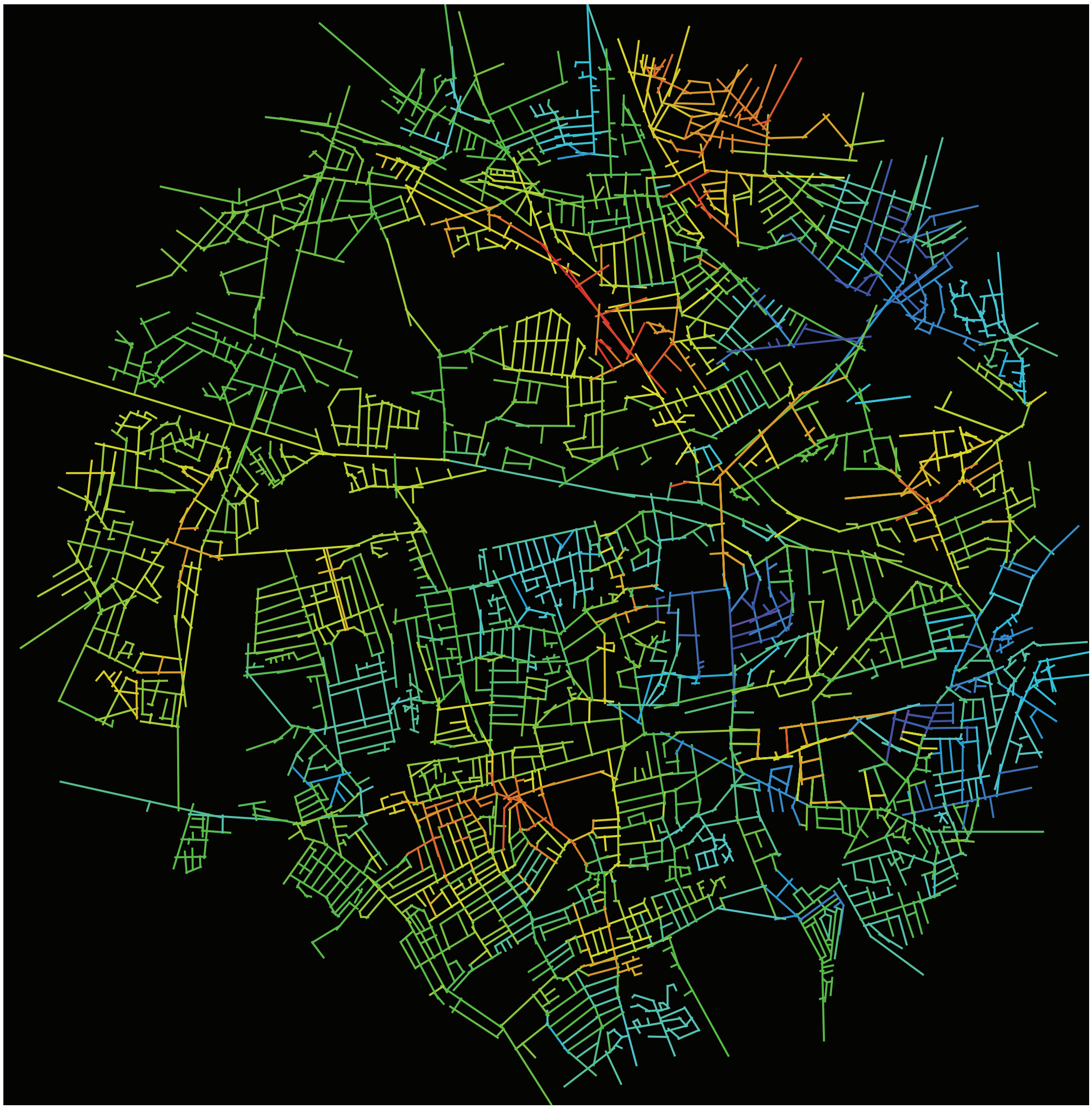


Figure 10.25 Axial map of Brentham Garden Suburb coloured with the point intelligibility (v=90) measure.

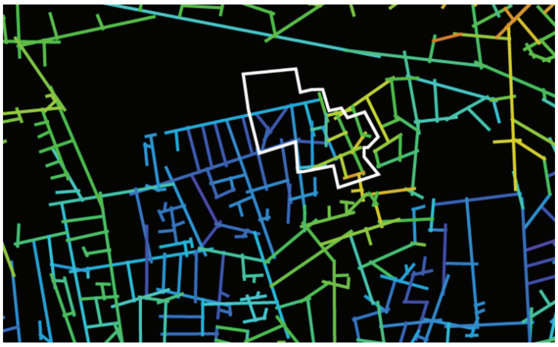


Figure 10.26 Axial map of B.G.S. coloured by the point synergy (v = 90) measure.

Figure 10.27 Axial map of B.G.S. coloured by the point synergy measure for V = 180.

Figure 10.28 Axial map of Brentham Garden Suburb visualising the point synergy measure Radius 4, V = 180.

number being delivered to the Brentham Way area. Thirty-three cards were returned (note that some cards arrived after the deadline for the Space Syntax Symposium, resulting in some of the difference in data presented in this paper compared with (Dalton 2006)). This was a return percentage of 11%, which is rather high for postal surveys. The textual results are presented in Table 10.4 8.7 and Fig 10.29. As seen in this table, only 76% returned the correct name, with 30% returning either the wrong name (typically Pitshanger) or a fusion of both names. Only 5 mentioned the 'received' or institutional name of Brentham Garden Suburb, indicating a weaker notion of received or institutional neighbourhood. On average, the respondents had lived there for 23.42 years (median 22, std deviation of 16.95 years, min 1 year, max 69 years), showing a strong degree of inhabitation and, as suggested by (Taylor, Gottfredson et al. 1984), a marker for a high degree of community. The respondents reported knowing an average of 28.5 other households (median 20, Std Deviation of

Figure 10.29 All respondents' neighbourhood boundaries (Conservation boundary in black) over axial map.

73.07, minimum of 0, and maximum of 400), suggesting a strong degree of social interaction between residents.

It should be noted that these values are very similar to those reported from the Hampstead Garden Suburb setting; that is, for comparative purposes, the residents have lived in the same neighbourhood for roughly the same amount of time and have roughly the same kinds of social networks. Hence, we would expect that if social and institutional factors dominated the definition of neighbourhood, we would see similar levels in certainty about the neighbourhood bounds to those of Hampstead Garden Suburb. It is interesting therefore to see that the name of the neighbourhood is more weakly held (76% against 88%) than in the Hampstead Garden Suburb case.

The drawn neighbourhoods were entered into a GIS system and are presented in total below. The data set presents a number of interesting observations. First, respondent 7305 returned the largest boundary, but also reported that they had lived in four different locations in the area (from 1963). They also reported one of the largest social networks (200+). This movement within an area suggests high satisfaction with the neighbourhood, but also leads to the reporting of the largest and most southerly neighbourhood. One could conjecture that this was in fact the sum of several local neighbourhoods, but was just conjecture and not enough to reject the boundary from the dataset.

The second observation was the high number of those reporting that their home street was highly off centre from their home neighbourhood. That is, people self reported being on or near the edge of their personal definition

CardID	Households	Residence	Name
7316	10	23	Pitshanger
7305	200	44	Brentham Estate
7306	40	20	Bentham
7306	20	40	Bentham or Pitshanger or Noth Ealing
7308	40	26	Bentham Garden Estate
7309	25	69	
7311	3	5	Brentham
7312	20	28	Brentham Estate
7318	30	8	Bentham Garden Estate
4101	10	41	Brentham Estate
4200	400	14	Pitshanger
4199	30	28	Bentham Garden Estate
4100	40	27	Pitshanger
4187	20	35	Bentham or Pitshanger
4102	0	1	Bentham Garden Estate
7005	16	13	Brentham Estate
7004	7	1.75	Bentham or Pitshanger
7002	15	16	Brentham Estate
7000	10	15	
7317	10	4	Brentham Estate
7314	25	53	Brentham Conservation
7313	20	61	Bentham
7310	30	17	Bentham
7303	6	22	Brentham Estate
7304	40	30	Bentham Garden Estate(mostly)
7322	8	10	Pitshanger
7319	20	23	Pitshanger
7320	50	3	Bentham
7321	30	32	Bentham Garden Estate
7302	30	13	Brentham Estate
7301	30	17	Bentham or Pitshanger
7315	12	30	Bentham
7003	12	3	Pitshanger

Table 10.4 B.G.S. respondents.

of neighbourhood. Nineteen cards (58% of the sample) (7316, 7306, 7307, 7308, 7309, 7313, 7318, 4101, 4100, 4187, 7002, 7000, 7314, 7310, 7304, 7322, 7320, 7302 and 7301) were deemed to be highly eccentric, with a strong bias to the west (left).

No respondent included the nearest Tube station (Hanger Lane), or indeed any Tube station, in his or her definition of their neighbourhood. Perhaps this reflected a disdain for public transit, but this does reinforce the significance of the eastern boundary reported by the respondents. Only 6 respondents (7003, 7321, 7303, 7005, 4102 and 4199) were deemed to have reported themselves near the centre of their neighbourhood, the others being either unmarked for a home street or without a neighbourhood bounds. This would certainly constitute evidence against the assertion of inhabitants reporting their neighbourhood as being self centred. Clearly, the urban configuration has a distorting effect on the region people reported as their neighbourhood.

Only one respondent (7004) returned their street as their neighbourhood. This example of the literal interpretation of neighbourhood (neighbourhood is where my immediate neighbours live) has been excluded from the analysis, as were the ones in the Hampstead Garden Suburb case.

It can be observed that, of the 33 responses (reporting boundaries), a number gave a large area. We can create two subsets, for those that included Pitshanger lane (numbering 20) and those that did not include Pitshanger Lane (9). These are shown in Fig. 10.30 and Fig. 10.31.

It can be seen from Fig. 10.34 that the residents not including Pitshanger Lane on the map appeared to be following the received notion of the Brentham Garden Suburb Conservation area. Two cases (green and purple in Fig. 10.31) appear to be reporting the area of constant synergy, which extends to the south of Brentham Way (red in Fig. 10.28). Given the general eccentric nature of the boundaries reported and the subset that appears to be very aware of the institutional and historic boundaries, it is suggested that the data is reporting a conflict between the institutional and historic boundary and what could be termed the natural boundary. It is suggested that when the areas surrounding the original Brentham Garden Suburb project were developed, they were well knitted into the existing fabric. This knitting created a new continuation of the original project, effectively enlarging the eastern portion. Thus, the change in urban configuration changed the spatial properties of the neighbourhood. The Pitshanger Lane respondents reported their intuitive spatial appreciation of this changed configuration.

To test this sub-hypothesis, the data was processed in three sets.

First, all the respondents were used to create an average (consensus) neighbourhood. The selected lines and the probability contour lines are presented in Fig. 10.32.

The second test was repeated for the Pitshanger Lane group, with the selected lines and the average boundary shown in Fig. 10.33.

The third test was the non-Pitshanger Lane group, the average boundary showing in figure 10.34 clearly covers a much smaller geographic area than the first two groups.

Figure 10.30 Respondents including Pitshanger Lane on map.

Figure 10.31 Respondents that did not include Pitshanger Lane on map.

Figure 10.32 Selected lines (red) from the average (consensus) neighbourhood.

Figure 10.33 Lines selected by the Pitshanger Lane group from screen dump of Interstice program.

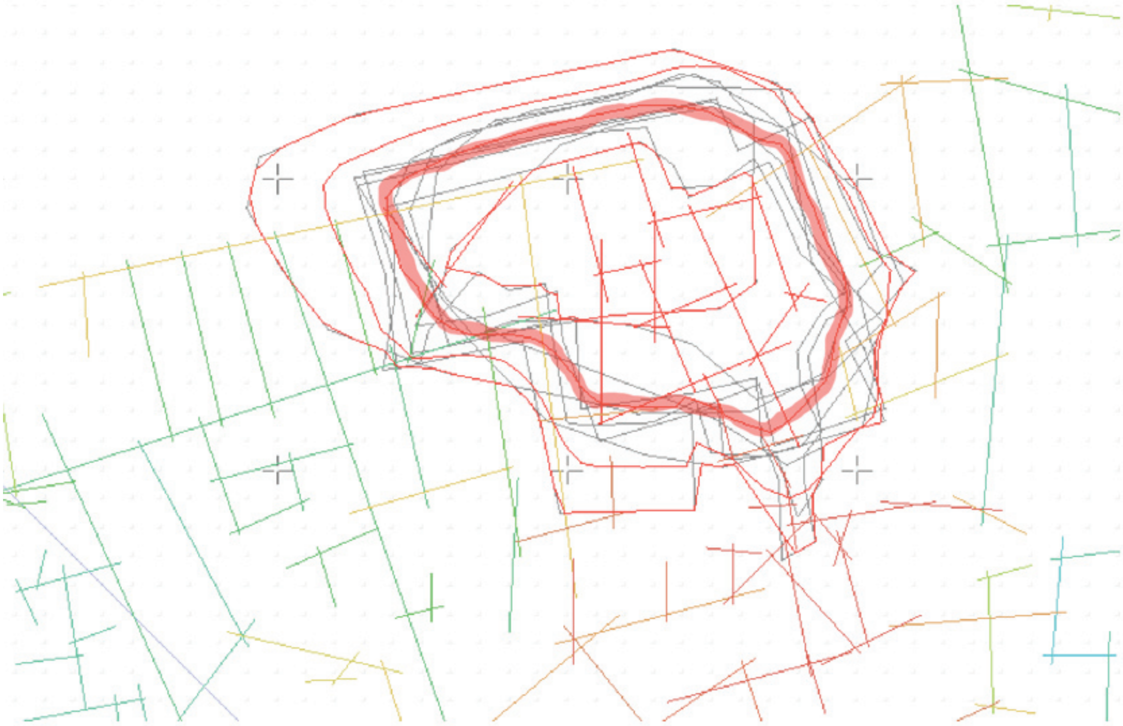


Figure 10.34 Non-Pitshanger Lane group with selected lines and average (consensus) neighbourhood.

Statistical analysis

We can see from Table 10.6 that the significance of point intelligibility and that of point synergy V = 90 are higher than for the received institutional group (Non-Pitshanger Lane Table 10.7), as well as that of both groups together (Table 10.5). This confirms the visual assay that the institutional (the conservation area) bounds cover two different natural neighbourhoods.

What appears to be demonstrated by this case is the possible conflict with the received notion of neighbourhood, which was historically created in this case, as the project was a building, economic and social experiment in cooperative housing. We can see from the point vicinity and point intelligibility maps that spatially there are two natural neighbourhoods, one we might term Pitshanger Lane (the blue area in Fig. 10.25) and the other the Institutional Brentham Way area (orange in the same

Measure	Intelligibility	Synergy R3	Synergy R4
Vicinity Used	90	90	90
Lines in Inside	32	32	32
Average inside	0. 3039394977968186	0. 4183366862125695	0. 4359202068299055
StdDev inside	0. 09189939914040474	0. 16320495483196873	0. 05550580974358099
Population	2474	2474	2474
Avg Population	0.24371008747763400	0. 344705784814514	0. 47206406198971196
StdDev Population	0.10530227595753200	0.1329300547148460	0.08868264045782200
Significance	-3.707412658791820	-2.552123971336420	3.683587746910280

Table 10.5 Statistical results for all respondents.

Measure	Intelligibility	Synergy R3	Synergy R4
Vicinity Used	90	90	90
Lines in Inside	46	46	46
Average inside	0.3157319779629290	0.4477886084629140	0.4535557549932730
StdDev inside	0. 09350527277325542	0.16206456864101000	0.07098485685133860
Population	2506	2506	2506
Avg Population	0.24371008747763400	0. 344705784814514	0. 47206406198971196
StdDev Population	0.10530227595753200	0.1329300547148460	0.08868264045782200
Significance	-5.2240500753824500	-4.313970236914840	1.7683975293734600

Table 10.6 The statistical results for Pitshanger Lane.

Measure	Intelligibility	Synergy R3	Synergy R4
Vicinity Used	90	90	90
Lines in Inside	17	17	17
Average inside	0.30577386258279600	0.430597243940129	0.42652802782900200
StdDev inside	0. 09429493400820514	0.14706732659772300	0.052295381770464500
Population	2506	2506	2506
Avg Population	0.24371008747763400	0. 344705784814514	0. 47206406198971196
StdDev Population	0.10530227595753200	0.1329300547148460	0.08868264045782200
Significance	-2.713777818232460	-2.408009763324390	3.5901808584248500

Table 10.7 Non-Pitshanger Lane group.

figure). The spatial origins of this separation can only be conjectured, but it is suggested that the smooth knitting in of the surrounding suburban structure might be responsible or, perhaps like the Hampstead Garden Suburb, it might be the result of changes in the phased growth of the project. It is suggested that this conflict between the spatial and social definitions of neighbourhood has created a slightly confused interpretation of neighbourhood, and it is this confusion that is reflected in the respondents' boundaries.

Clearly, this work confirms the hypothesis that areas of continuous synergy and intelligibility reflect the 'natural' neighbourhood, but it does so in a complex way that is to be expected of real world data. Like Lynch, we have gone out with one set of bounds and come back with two more interesting ones. In this case, the resultant sub-groups have split our original bounds in two.

Chi-Squared statistical test for Link based agglomerative hierarchical clustering

The method of agglomerative hierarchical clustering that was used to find the 64 clusters of near continuous values was used again and the values, including the chi-squared values, are presented in the table below. As presented above, the simple average consensus boundary method was chosen for consistency with the previous results.

In Table 10.8, as expected, we find that randomness produces a very low value of 60. In this case, orientation performs significantly better than this, indicating that the orientation of streets is some measure of the neighbourhood

Method	Chi squared	p-value	True, Positive	False, Positive	False, Negative	True, Negative
Point_ Synergy R_4_V180	328.0533	< 2.2e-16	16	11	48	2417
Point_Intel_ V180	407.49	< 2.2e-16	17	10	42	2423
EMD=6	257.8949	< 2.2e-16	17	9	77	2389
Average Integration	315.2433	< 2.2e-16	19	8	75	2390
Orientation	217.603	2.20E-16	22	5	155	2310
Random	60.0866	9.08E-15	9	18	82	2383

Table 10.8 Comparison of neighbourhood find methods for Brentham Garden Suburb

area. EMD radius 6 appears next. While from an order point of view this is the third from the bottom, it is more than four times the randomness value, suggesting that EMD performs satisfactorily in an absolute sense. However, it should be pointed out that the test performed by R did report that "Chi-squared approximation may be incorrect" indicating that the samples may not have been fully normally distributed. Average integration performs well here, making it also recognise something about Brentham Garden Suburb as a place. Point synergy radius 4 with a vicinity of 180 comes in second, having a chi-squared value of more than five times that of the randomness value. Finally, and most surprisingly, we find that the intelligibility value has the highest chi-squared value. The shift from worse than randomness in Hampstead Garden Suburb to the top performer suggests that perhaps point intelligibility does measure some aspect of the neighbourhood value, but does so in an inconstant way.

It can be noticed that, in this case, all of the chi-squared values are much lower than both the Hampstead Garden Suburb and Boston cases. The argument that is put forward in this thesis is that the lower values reflect the lower certainty given by the axial maps and the lower levels of certainty given by the respondents. The suggestion is that while Brentham Garden Suburb was built like Hampstead Garden Suburb, with a degree of isolation, unlike Hampstead Garden Suburb, it was initially much smaller and later developers integrated much more strongly with the original development. Thus the original neighbourhood is much more 'blurred' than in the Hampstead Garden Suburb case, a fact that is reflected both in the spatial patterns and the degree of the respondents' certainty about their neighbourhood. [here]

Speculatively, was this blurring of Brentham Garden Suburb a failure or a success? From the viewpoint of the surrounding and, arguably, less architecturally accomplished developments, the successful integration with the original Brentham Garden Suburb development is a positive step, creating a spatially nearly seamless mesh for the surrounding fabric. This could be contrasted with the 'gated community' approach of looking for complete segregation from adjacent developments to maintain some notion of 'uniqueness'. Alternatively, it could be argued that this integration into the surrounding fabric has served to

Figure 10.35 Map of Clerkenwell with red outline showing official bounds.

erase the original identity. If we take the longevity of occupation as a measure, and given its similarity to that of Hampstead Garden Suburb, then perhaps the integration, while erasing the original identity, has served to create a larger and as positive whole.

Clerkenwell

The previous data sets were useful in that the neighbourhoods had strong institutional boundaries that, while contributing to the definition of the area, appeared poorly in neighbourhood results. The final data set is Clerkenwell (see fig 10.35), a more historic and central area in the London Borough of Islington. Clerkenwell differentiates itself from the previous data sets by being a product of a less formally planned historical growth process. Clerkenwell is also the subject of other studies, such as the VIVAcity 2020 project (Perdikogianni, 2005) and is mentioned by Neal (Neal 2003) as a prototypic 'urban village' combining a mixed social and economic use. Like the Beacon Hill area, Clerkenwell is also topographically not a level site. There is a sharp gradient up the Pentonville Rd to the north, with gradients leading downhill from Islington to the North to the flatter areas of the South.

The axial map used for this analysis was one created for a separate research project and has largely been checked with a site visit (during leafleting). This has the advantage that the spatially complex area called Barbican to the Southwest has been modelled with a large number of unlinks, a facility that was not available with the larger M25 map used in the two garden city projects.

We can see that the area of Clerkenwell sits inside a ring of large scale integrators, with Pentonville Rd (and Islington) to the North, Greys Inn road and the Bloomsbury Area to the west, and High Holborn to the south. This area has a number of tube stations on its periphery (Angel, Farringdon, Barbican and possibly Kings Cross and Old Street further to the West) but none internal to the area.

From Fig. 10.37, we can see that two sides (Gray's Inn Rd, Pentonville & City Rd) of the boundary are defined by strong choice lines, while the other two sides are unbounded. No strong choice lines intersect the Clerkenwell area.

The angular axial map (Fig. 10.38) shows that Theobald Rd, Clerkwell Rd and Old Street now form a stronger integrator, as does the Kings Cross Rd, Farringdon Rd combination to the west. Exmouth Market and Rosebury Avenue also become stronger local integrators.

Fig. 10.39 shows the strong mix of local integration patterns, both within Clerkenwell and surrounding it. The large blue area to the southeast is the Barbican project.

Fig.10.40 shows that the area of central Clerkenwell is coloured red by the Read average integration neighbourhood finding mechanism, but that it does not appear to give a strong edge to the location of the boundary of Clerkenwell, merging slightly with the city of London. Noticeably, Bloomsbury, Barnsbury and the South Bank appear to be differentiated.

We are beginning with a very large and undefined area for Clerkenwell. Given the size and history of our previous experiments, it was likely that we would find a number of local sub-areas. To this end, a feature of webmap@home was used to exclude lines outside the approximate area of the Clerkenwell region. This had the effect of using the colour spectrum more effectively by only using values in the area of interest to set the spectrum scale. Fig. 10.41 shows the centre of the Clerkenwell map. Looking at the enhanced version, we can see that an area at the heart of Clerkenwell is a strong dark blue colour, but that it has been split in two by lighter coloured lines, Rosebury Ave and Myddelton St/Exmouth Market. The light green colour surrounds the blue heart, reaching partially out into the Gray's Inn Field area, down to Farringdon, but stopping abruptly at Pentonville Rd and City Rd to the North.

Using the same exclusion method to intensify the cross site colour differentiation, we can see that the point synergy map in Fig. 10.42 is spread more evenly than before. The small divergence between point intelligibility and point synergy is novel and interesting. From this, we can see that Kings Cross Rd and Farringdon Rd appear to be a small light blue barrier between the larger central Clerkenwell and Gray's Inn Rd, that is, these areas are similar in value but are not continuous from the point intelligibility view.

Looking at a larger scale, we see in Fig. 10.43 that the larger Clerkenwell area does appear to be differentiated from Barnsbury/Islington to the North, Bloomsbury to the west and The Barbican/The City to the south. There are weak barriers between Clerkenwell and the Gray's Inn Field area to the west and Farringdon to the south. This is strongly suggestive of the idea that the vicinity 180, radius 4 measure is picking up the larger scale Clerkenwell area.

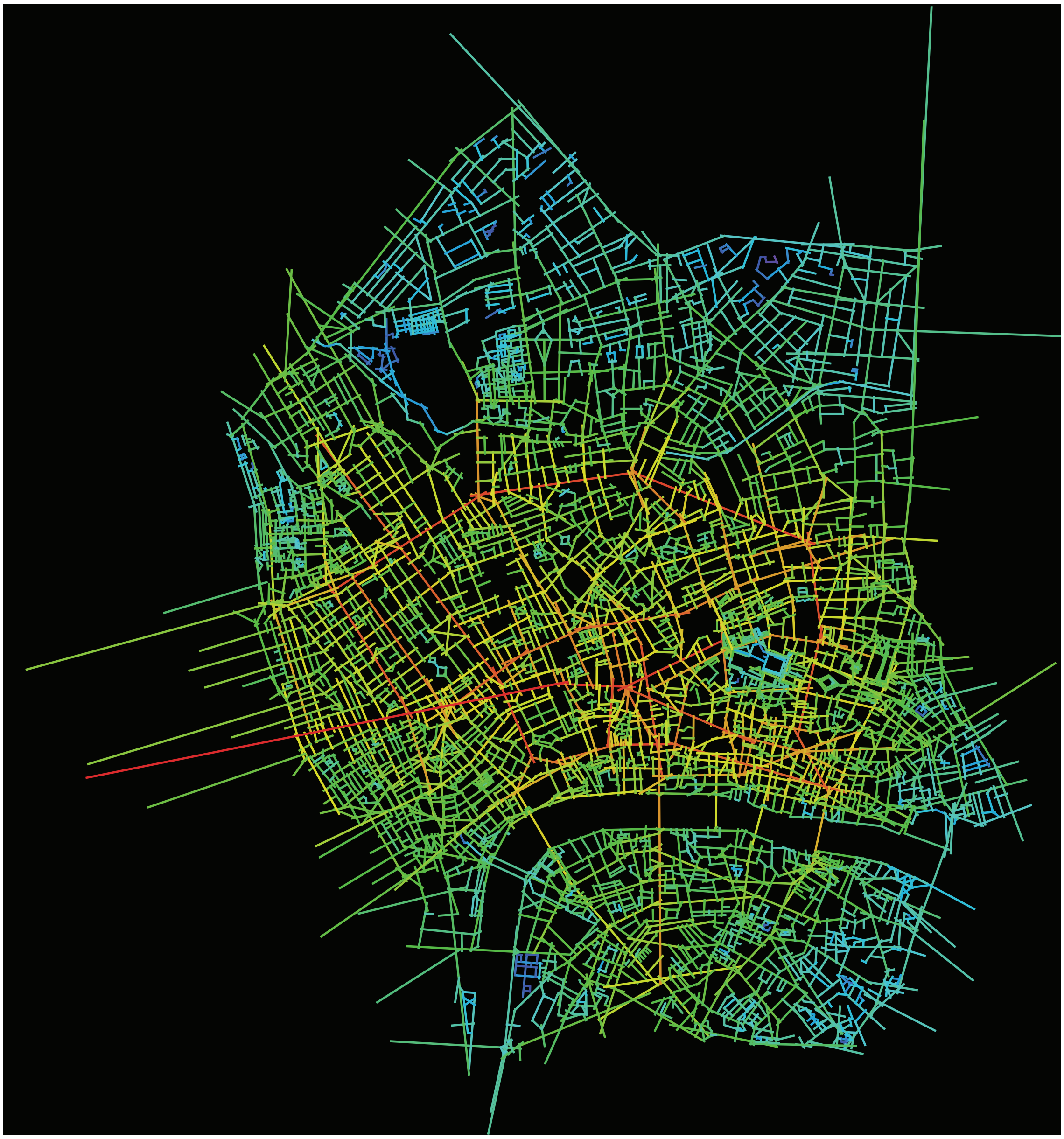


Figure 10.36 Axial map of Clerkenwell coloured by global integration.

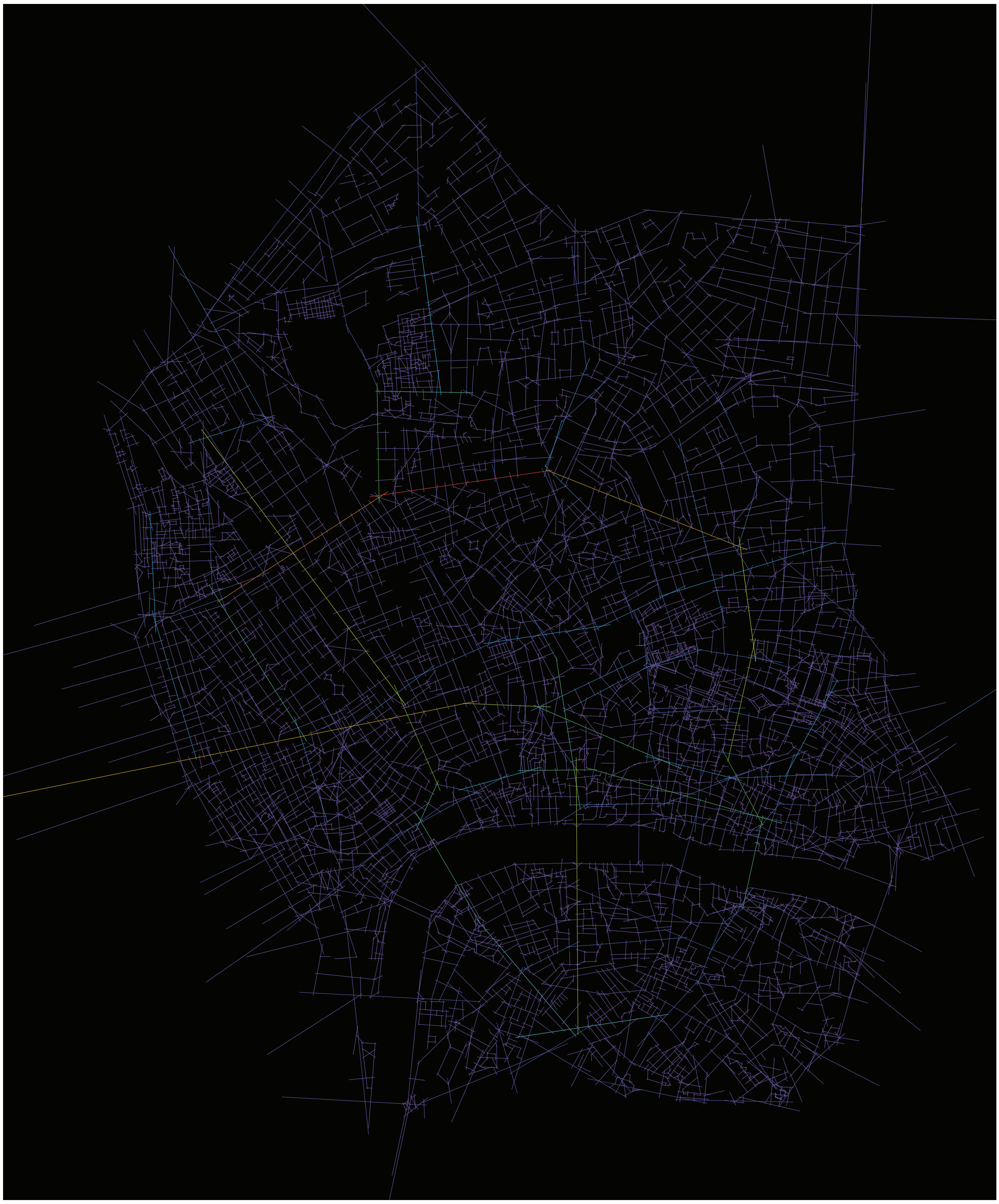


Figure 10.37 Axial map of Clerkenwell and surrounds coloured by global choice.

Figure 10.38 Axial map of Clerkenwell and surrounds coloured by global axial angular integration.

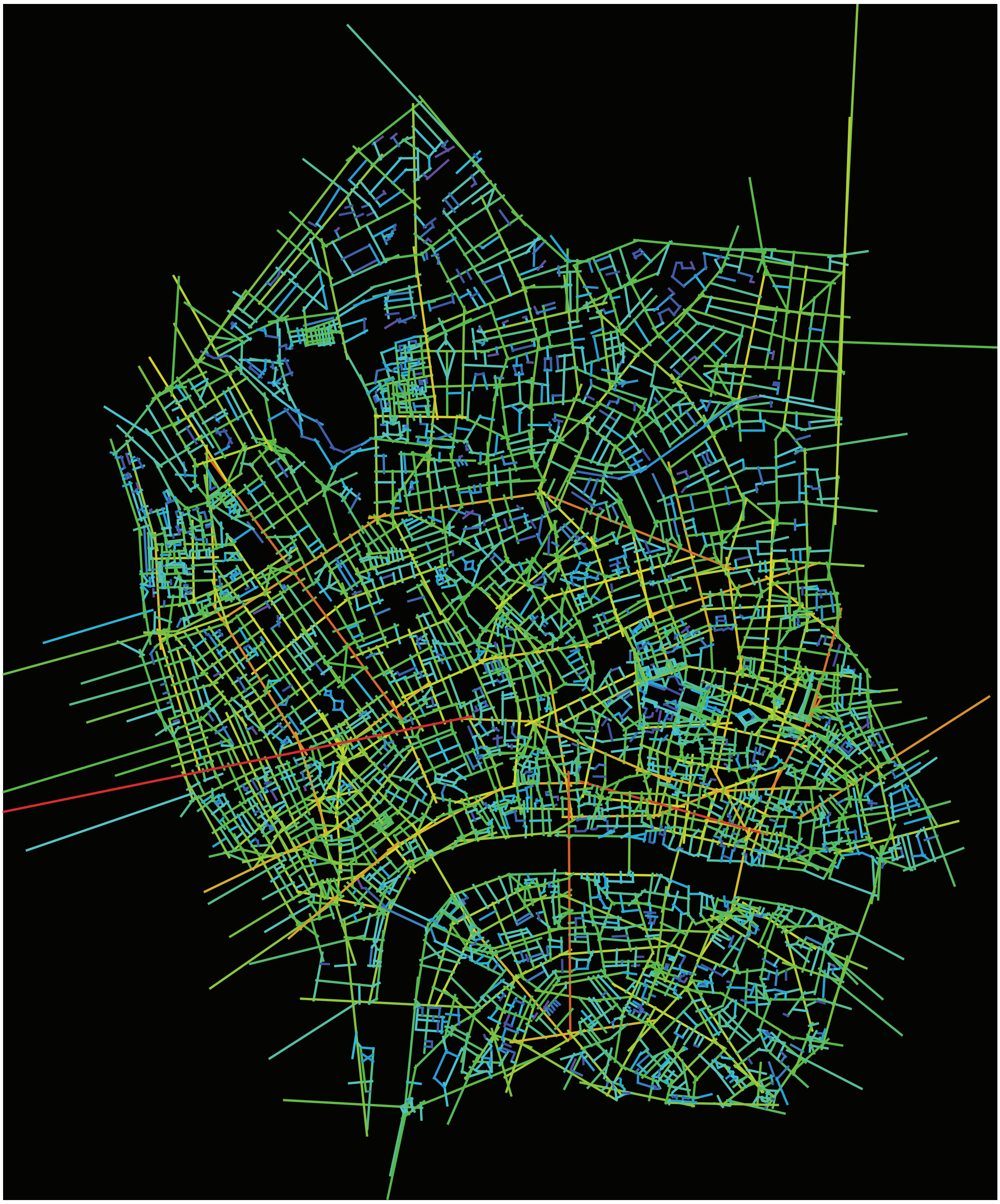


Figure 10.39 Axial map of Clerkenwell and surrounds coloured by the Radius 3 integration measure.

Figure 10.40 Axial map of Clerkenwell and surrounds coloured by local Radius 3 average of Radius 3 integration.

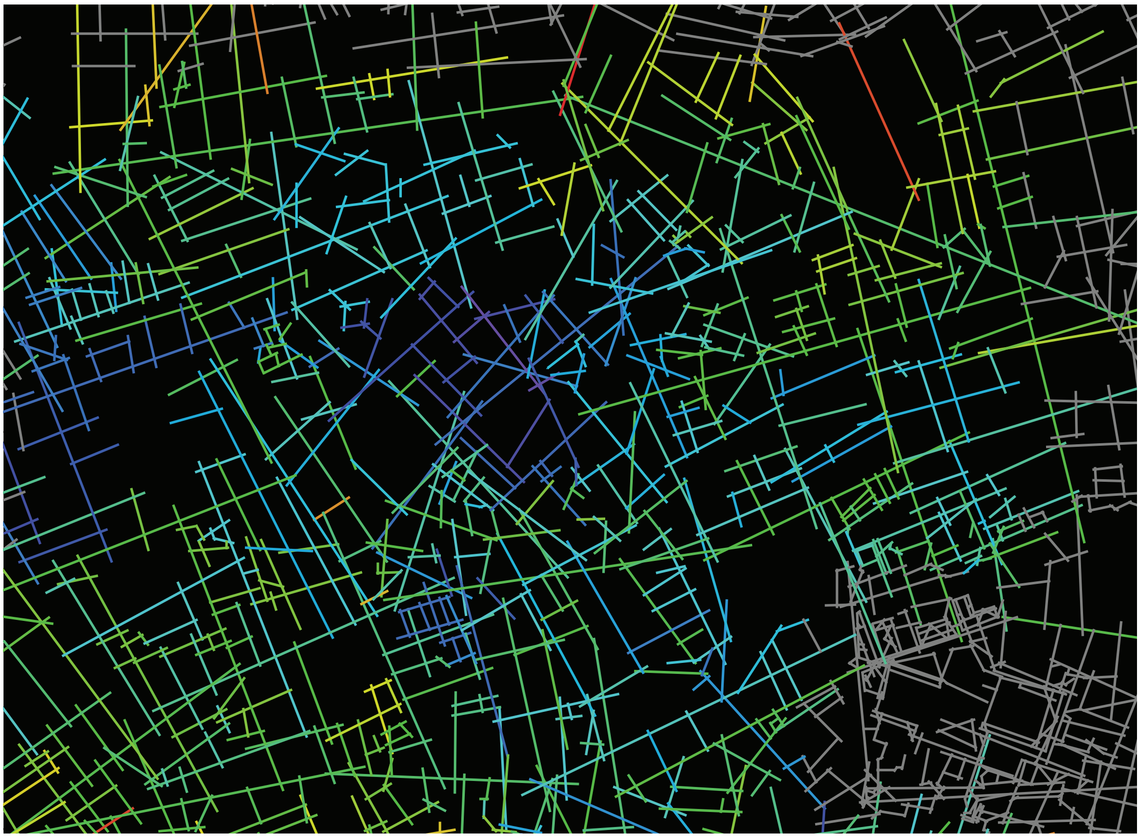


Figure 10.41 Axial map of Clerkenwell coloured by the point intelligibility (v = 90) measure.

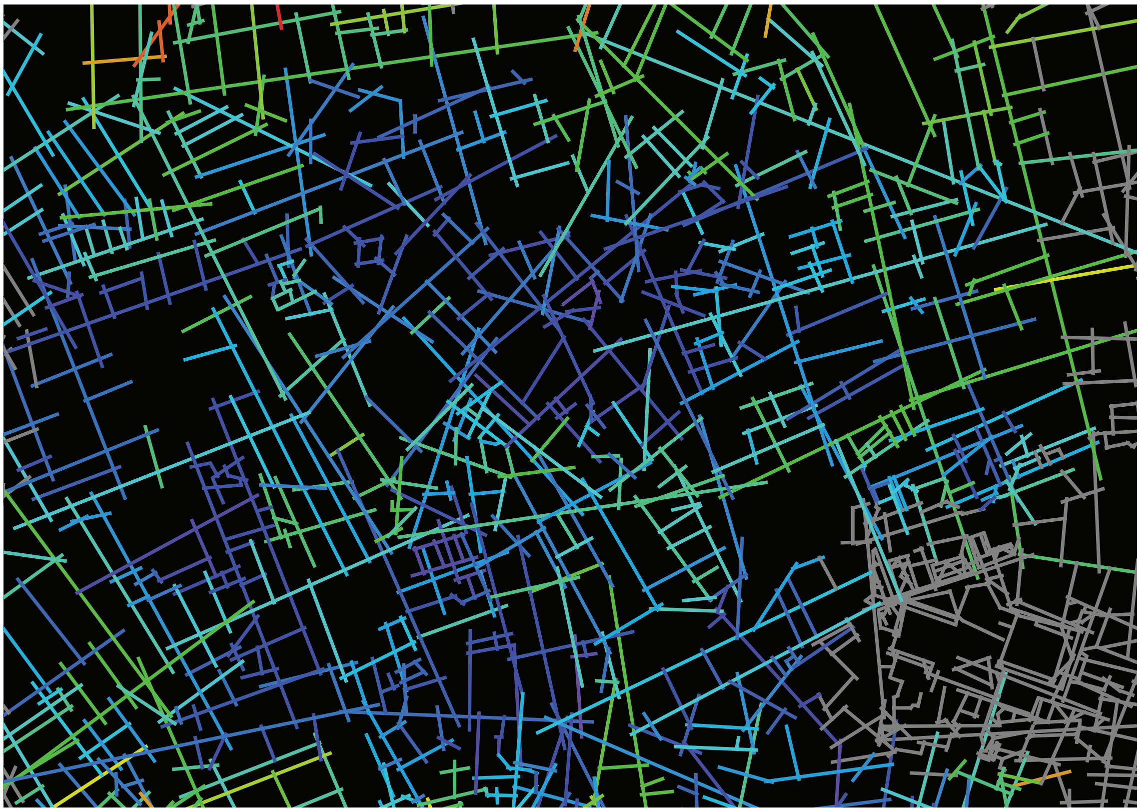


Figure 10.42 Axial map of Clerkenwell coloured by the point synergy (v = 90) measure.

Figure 10.43 Axial map of Clerkenwell and surrounds coloured by the point synergy measure for V = 180, R = 3.

Survey Returns

Seven hundred cards were distributed over a number of runs with 69 returns. The initial card distribution began on 3/10/2006. On average, the respondents had lived there for 19.4 years (median 15, std deviation of 19.4 years, min 1 year, max 86 years), showing a strong degree of inhabitation and, as suggested by (Taylor, Gottfredson et al. 1984), a marker for a high degree of community. The written information is presented in Table 10.9 below. It should be noted that 18 respondents put themselves near the edge of their neighbourhoods, reinforcing the idea that the sample does not represent those who believe that they are at the centre of their neighbourhoods. It should also be noted that return C1020 exhibited a discontinuous neighbourhood, that is, the neighbourhood looked like two balloons tied together with a string. This was a highly interesting return in that it suggests that not all people view their neighbourhood as a purely continuous thing. Return C1022 also demonstrated an unusual and strongly dendritic structure for neighbourhood, suggesting that movement and through movement played a strong role in their unique view of space.

It is clear from studying the results in Table 10.9 that many residents are reporting the larger named area (Clerkenwell) as their neighbourhood. We see some partial confusion between Finsbury or Farrington and Clerkenwell. What is clear is that none of the participants reported a neighbourhood that strongly followed the intuitional boundaries. Most interestingly, we have a number of reports of a location called Amwell Triangle or Amwell Village, including the comments ‘the village (to the locals)’. A property article in the Telegraph (McGuigan 2005) reports one resident, Linda Parkinson-Garde, as saying ‘We have a real village atmosphere here.’ More significantly, respondent C1028 describes their neighbourhood as ‘no distinguishing name’. Clearly, from these responses, we must expect to find at least two sub-areas in the respondents’ boundaries.

Because of the large number of respondents, we can see that the responses and their geographic distribution are hard to differentiate. To cope with this, a new visualisation mechanism is now introduced, that of the neighbourhood density map. This is constructed by filling each neighbourhood polygon with a single colour (grey in the examples below) and giving each polygon the same level of transparency (about 26% in the example). Areas where only one respondent responded with Clerkenwell are shown as a light grey, with the colour intensity building up where more respondents outlined that area as part of their neighbourhood. The central-most overlapped areas showing the greatest density of commonality of neighbourhood emerge as black. In effect, we can regard these visualisations as the probability that the sample population regard them as their neighbourhood.

It is obvious from Fig. 10.44 that there is no one single point or area that is common, making a direct comparison with point synergy a little premature. Fig. 10.45 shows that the central area of Clerkenwell is regarded as the core of the reported neighbourhood areas. Removing those who gave very broad areas as Clerkenwell, that is, those who are reporting the root or top level region known as Clerkenwell, leaves those who are responding on a more local level (see Fig. 10.46). What makes

CardID	Local	Residence (years)	Name
C1072	no	1	Exmouth market
C1071	yes	28	Clerkenwell
C1070	yes	20	Northton Rd
C1069	yes	12	Finsbury/ Clerkenwell
C1068	yes	5	
C1067	yes	86	Finsbury
C1066	No	4	Islington
C1065	yes	12	Finsbury
C1064	yes	20	Amwell st/village
C1063	yes	3	Kings Cross
C1062	no	8	Clerkenwell
C1061	Yes	1	Finsbury
C1060			
C1059	no	13	Finsbury/ Clerkenwell
C1058	Yes	1	Clerkenwell
C1057	yes	26	Finsbury
C1056	yes	28	Clerkenwell
C1054	yes	29	Clerkenwell
C1053	yes	5	Clerkenwell
C1051	no	3	Withington Square
C1050	no	5	Clerkenwell
C1049	yes	10	Mydoeton st
C1048	yes	11	Clerkenwell
C1047	yes	18	Finsbury
C1046	Yes	18	Clerkenwell
C1045	yes	19	Finsbury
C1044	yes	57	Northampton Rd
C1043	yes	4	Clerkenwell
C1042	yes	22	Amwell village
C1041	yes	23	
C1040	yes	37	Finsbury
C1039	no	9	Clerkenwell
C1038	yes	60	Amwell St
C1037	yes	59	Finsbury/ Clerkenwell
C1036	yes	9	Clerkenwell
C1035	yes	31	Clerkenwell
C1034	yes	20	Clerkenwell
C1033	yes	20	
C1032	no	2	Clerkenwell
C1031	yes	19	Loyd Barker estate
C1030	no	5	Clerkenwell
C1029	Yes	12	Bedlam!
C1028	YES	25	no disntive name
C1027	yes	11	
C1026	Y	4	Amwell St
C1025	yes	24	Rosebery Triangle
C1024	Yes	34	
C1023	Yes	26	Clerkenwell
C1022	yes	15	Clerkenwell
C1021	yes	18	Clerkenwell
C1020	yes	35	Clerkenwell, Fisbury
C1018	yes	15	Clerkenwell, Fisbury
C1017	yes	38	Finsbury
C1016	no	6	Farringdon or Angle
C1015	yes	3.5	Kings Z/ Clerkenwell
C1014	yes	82	the village
C1013	yes	32	Amwell village
C1012	yes	2	Loyld Baker Street
C1011	Yes	10	Clerkenwell
C1010	yes	3.5	Clerkenwell
C1009	Yes	25	Clerkenwell
C1008	Yes	3	Finsbury
C1007	Yes	1	Joseph Trotter Close
C1006	Yes	7	Finsbury
C1005	yes	6	Amwell st/village
C1004	yes	79	Clerkenwell
C1003	Yes	21	Wilington Square
C1002	yes	1	Clerkenwell
C1000	yes	20	Clerkenwell

Table 10.9 Results for Clerkenwell survey returns.

Figure 10.44 All respondents' neighbourhood boundaries over axial map.

this figure interesting is that for those that report smaller neighbourhoods, it looks like the street known as Exmouth market is at the centre of the most common (highest probability or black) part of the picture. It should also be noted that this figure looks like a butterfly, with the body along Exmouth Market.

If we only include those items of the reported neighbourhoods that included the term village or Amwell, or are located in that area, we can see that there appears to be a degree of commonalty between them. Referring to Fig. 10.47, we can see that this sub-area appears to account for a number of responses for those areas that are above Exmouth market and do not include it. Looking at the point synergy map, but reducing the vicinity parameter to 65, we get Fig. 10.49 below. Curiously, we appear to have an area of continuous light blue turning to green that seems to be approximately the Amwell Village area (see Fig. 10.50).

What appears to be happening is the same sub-area effect found in Lynch's Beacon Hill study. While the official area is quite broad, it contains a sub-area that can be identified by using a smaller vicinity value. Amwell Village has no official status or apparent boundary; it appears to be a term emerging from the local population to describe an area (a place) that they have in common and have some attachment

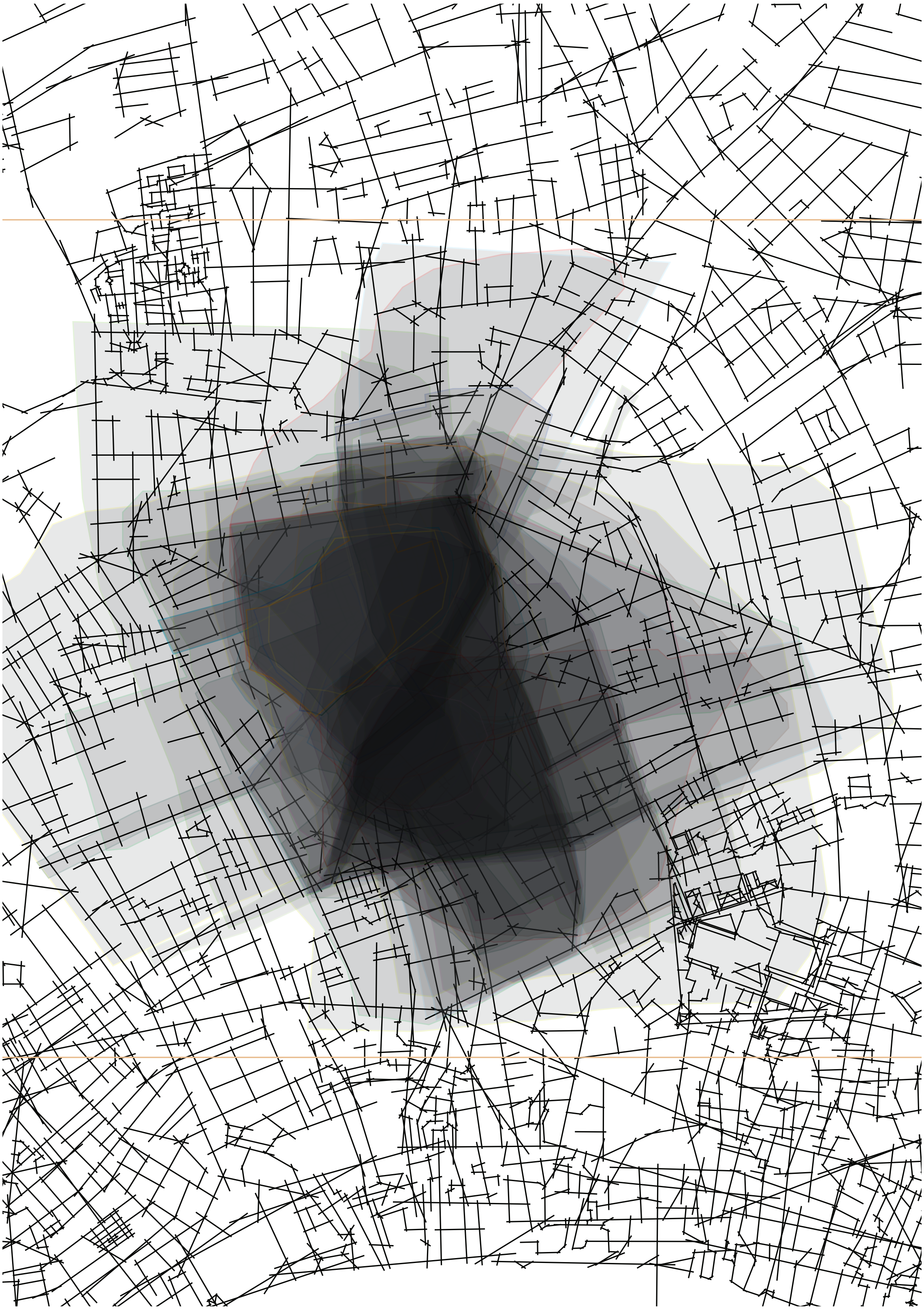


Figure 10.45 Density map of all respondents' neighbourhoods where darker areas show more commonality.

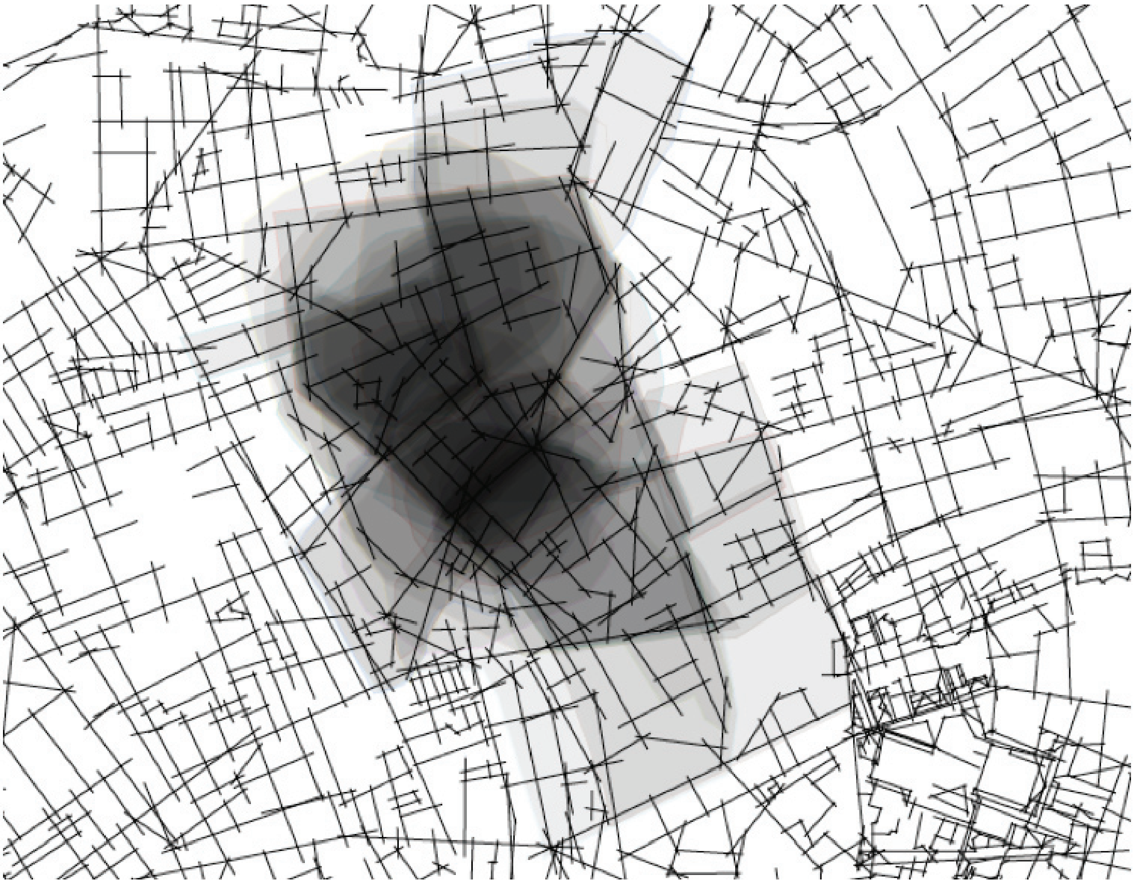


Figure 10.46 Density map of central respondents' areas showing Exmouth market as most common zone (black).

Figure 10.47 Eight respondents mentioning village or Amwell, or in apparent locality.

Figure 10.48 Clerkenwell coloured by Point intelligibility Vicinity 65 with Village of Amwell area highlighted.

Figure 10.49 Photograph of Amwell Street taken during the data collection exercise.

to. For example, Liz Thorton is quoted as saying, 'We work very hard to preserve the area from negative development and to keep the village-like atmosphere.' She said, 'The people who live here are very supportive and everyone takes an interest in life on the street.' Jon and Gina Tubbridge were similarly quoted as saying 'Amwell still has community spirit but not like it used to - we need to work together to stop it disappearing', or Linda Parkinson-Garde, 'We have a real village atmosphere here.' (McGuigan 2005). Or, 'For better or (more probably) worse, Amwell has entered realtor-speak and estate agents now advertise properties as being within "Amwell Village." Local shops have even started to include "Amwell Village" in their addresses' (Boerner (Boerner 2006)). Anecdotally, this and the spontaneous formation of The Amwell Society (http://www.amwellsociety.co.uk/) appear to suggest a sub-area in the process of being recognised and valued by its inhabitants. Thus, we can see that that area is not predefined in the manner of Hampstead Suburb or Brentham Garden suburb, but is emerging from the interactions of the residents. It is significant then that the Amwell Village area reported by the residents (in one case even though they could not name it) corresponds to the spatial continuity of the point intelligibility measure at a smaller vicinity value.

This process could be hypothesised as a case of a small sub-area beginning to differentiate itself. The spatial bounds that defined the natural spatial neighbourhood are being intuitively read by the residents and are informing the social connections that are being formed in the area. It has been reported that the area was previously mostly council owned and the right to buy has permitted private ownership and high social status residents to move in (McGuigan 2005). Thus, the new residents are in a stronger position to begin to articulate and formalise the area. It is possible that Amwell Village may have had previous incarnations; the area was reported as being known as "Little Italy" from the 1850s to the 1960s, and so may have had a different name to cover approximately the same geographic area. Alternatively, given that point synergy and point intelligibility are measures of the continuation of structure or configuration, in the larger context we might find that spatial interventions elsewhere have altered the local spatial structure, causing the area to emerge relatively recently. Perhaps what we are seeing in Amwell Village is the emergence of a natural neighbourhood or the conversion of the potential for neighbourhood becoming place, a factor for further study.

Exmouth Market

If we remove the Amwell Village neighbourhoods, personal neighbourhoods and those that appear to be matching the outer bounds of Clerkenwell, we arrive at Fig. 10.50. Examining this, we notice a number of regularities. First, Pentonville Rd is a common edge to the north. Secondly, we see that a number of neighbourhoods border the Kings Cross Rd, Farringdon Rd area, which as an integrator is a weak choice line (compared to Gray's Inn Rd). Finally, the eastern portion has no distinct boundary, except for St. John's Street, leaving a large area of Clerkenwell outside most of the respondents' neighbourhoods.

It is worthwhile to examine the responses a little more closely. Exmouth market appears to be a strong edge for many of the neighbourhoods.

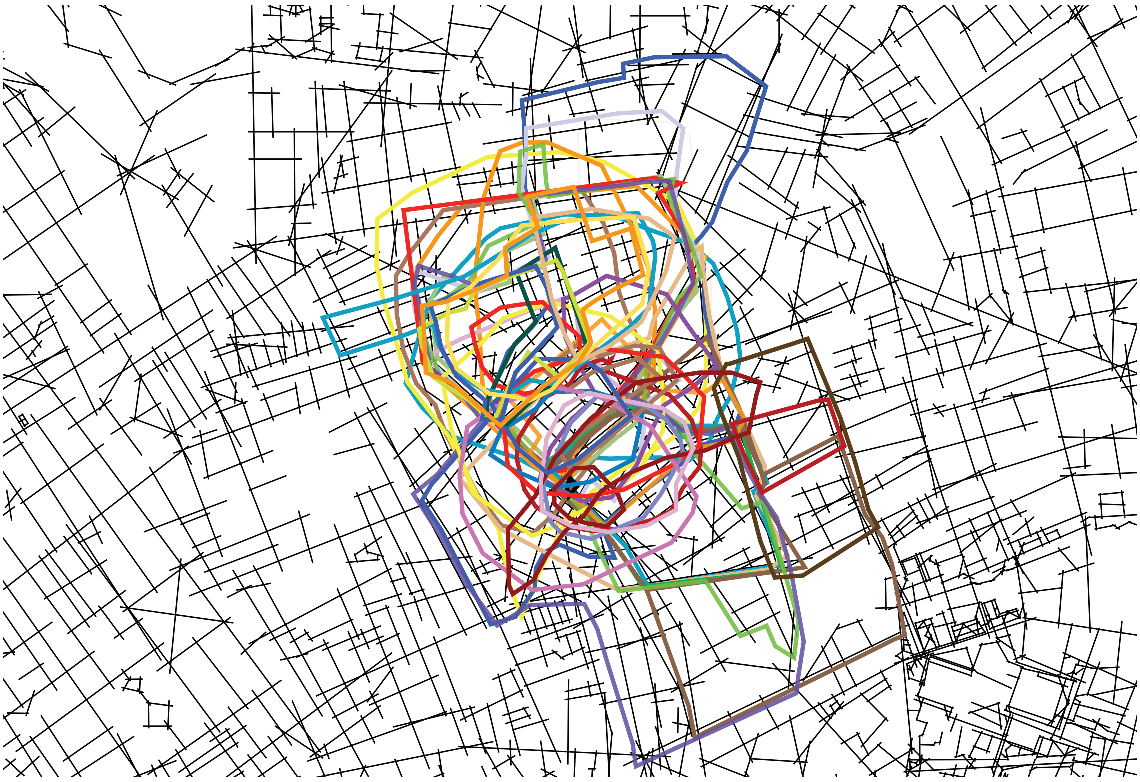


Figure 10.50 Remaining largely Exmouth Market centred neighbourhoods.

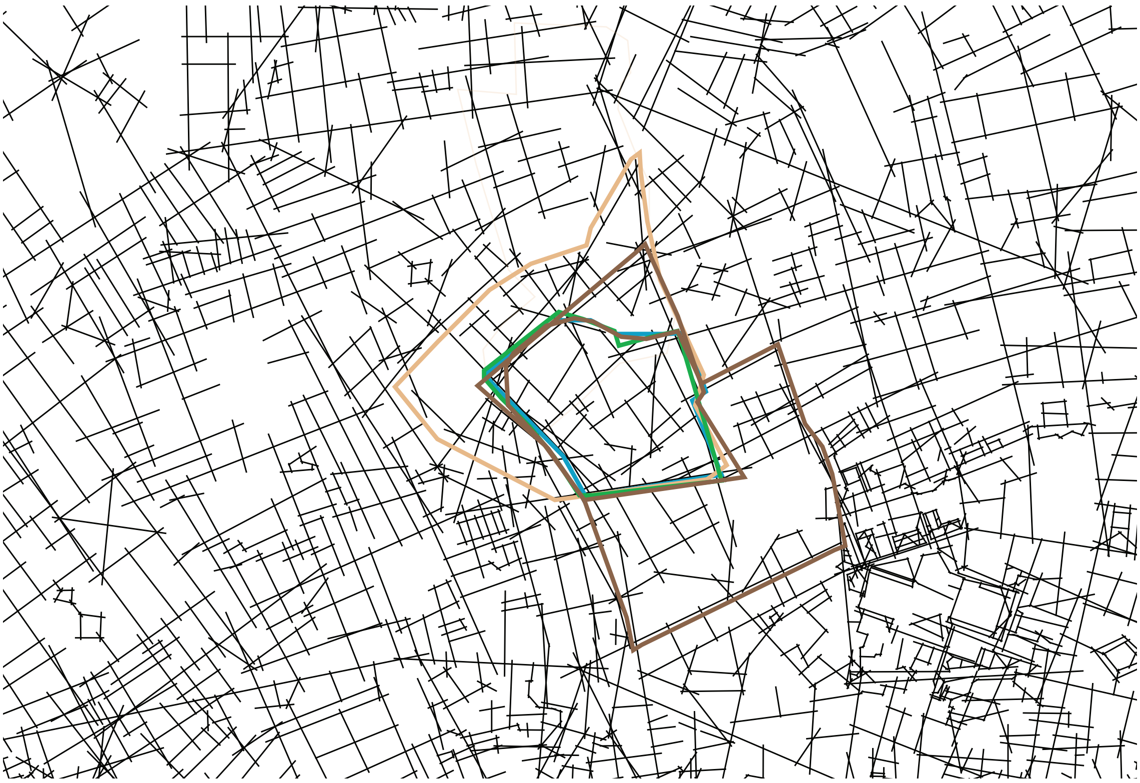


Figure 10.51 Respondents including Exmouth market to the south.

Figure 10.52 Respondents including Exmouth Market to the north.

Figure 10.53 Respondents including the areas to the north and south of Exmouth market.

We can divide the results into those that lay outside Exmouth market and those that include it (see Fig. 10.51, Fig. 10.52 and Fig. 10.53).

Inspecting Fig. 10.51, we can see strong commonalties between the areas returned, including a number that nearly match. This commonality is also present in Fig. 10.52. If we exclude most of the area surrounding Clerkenwell and process a point intelligibility at vicinity 90, we can create a more detailed map (see Fig. 10.54). Studying this map, we can see the local differentiation that was partly discernable in Fig. 10.41 above. Looking closely allows us to see the lighter lines of Exmouth Market/Myddelton Street and Rosebery Avenue crossing or rather partitioning the darker area. From this, we might conclude that from a point intelligibility view, the area to the north and south of Exmouth Market are two separate areas, but overlap over a strong local utility area, that of Exmouth Market itself. Functionally, we are seeing the area partitioned by both a change in spatial continuity and a medium local integrator (Rosebery Avenue). Occasionally, people join the north and south partition together, giving Fig. 10.53.

In this analysis, we can than process each side of Exmouth market against the partitioned area of synergy V = 90.

Statistical Analysis

Statistically, we have three hypotheses to test. First, we need to test whether the large area respondents are reporting a larger area at a high

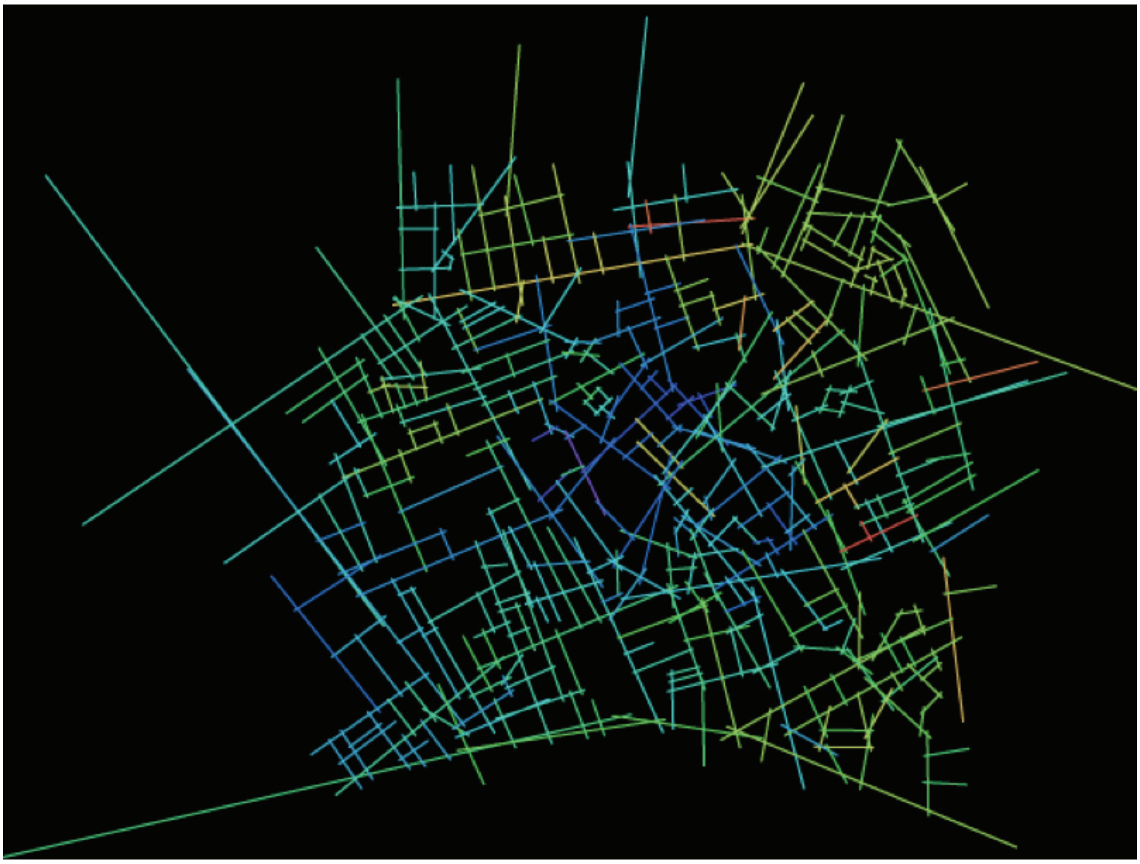


Figure 10.54 An isolated core of Clerkenwell coloured by point intelligibility V = 90.

vicinity. Secondly, we need to test whether the area known as Amwell, the Village or Unknown does constitute a nested area at vicinity 65. Finally, we need to test both wings centred on Exmouth Market to see whether they are returning the 'inner' area defining the core of Clerkenwell (the largely black areas on the neighbourhood density map of Fig. 10.45).

Clerkenwell Area

It does seem natural that when speaking to a stranger, a respondent would give the larger well known area to describe their neighbourhood. This is especially true if some included their route to the tube station (Angel) as part of 'the area of the city in which you live'. As we discovered in the Lynch Beacon Hill case, we might expect to find the broad area of Clerkenwell to be defined by a larger vicinity radius, such as V = 180. From Table 10.10 below, we see that both point intelligibility and point synergy appear to have a non-random sample of the area (Z test significances of –19.9 and –31.5, respectively, well beyond the 95% confidence level). The vicinity V = 180, R = 4 map appears to have a highly compact range of values (0.888 to 0.602, with most of the values near 0.671), as explained previously. If the radius and vicinity are raised to a high level, then the area returned will be a larger district, for example North or South London. This is to be expected; when vicinity = the size of the system (the number of nodes or dimensions), then the point intelligibility and point synergy

	Point Intelligibility	Point Synergy	Point Synergy
Vicinity	180	180	180
Radius	3	3	4
Neb Average	0.474	0.699	0.666154806
Neb N	176	176	176
Neb Stdev	0.077	0.072	0.010445793
All Average	0.358	0.528	0.668464386
N all	4718	4718	4718
All Stdev	0.092	0.128	0.012883976
Significance	**-19.956**	**-31.540**	**2.933241398**

Table 10.10 Results for Respondents returning all of Clerkenwell.

	Intelligibility	Point Synergy	Point Synergy
Vicinity	65	65	180
Radius		3	4
Neb Average	0.559	0.774	0.644
Neb N	16	16	16
Neb Stdev	0.422577085	0.049348939	0.003773955
All Average	0.402	0.587811996	0.642787564
N all	4718	4718	4718
All Stdev	0.134340659	0.153440385	0.020282998
Significance	**-5.939472088**	**-15.11637563**	**0.786**

Table 10.11 Results for Amwell Village.

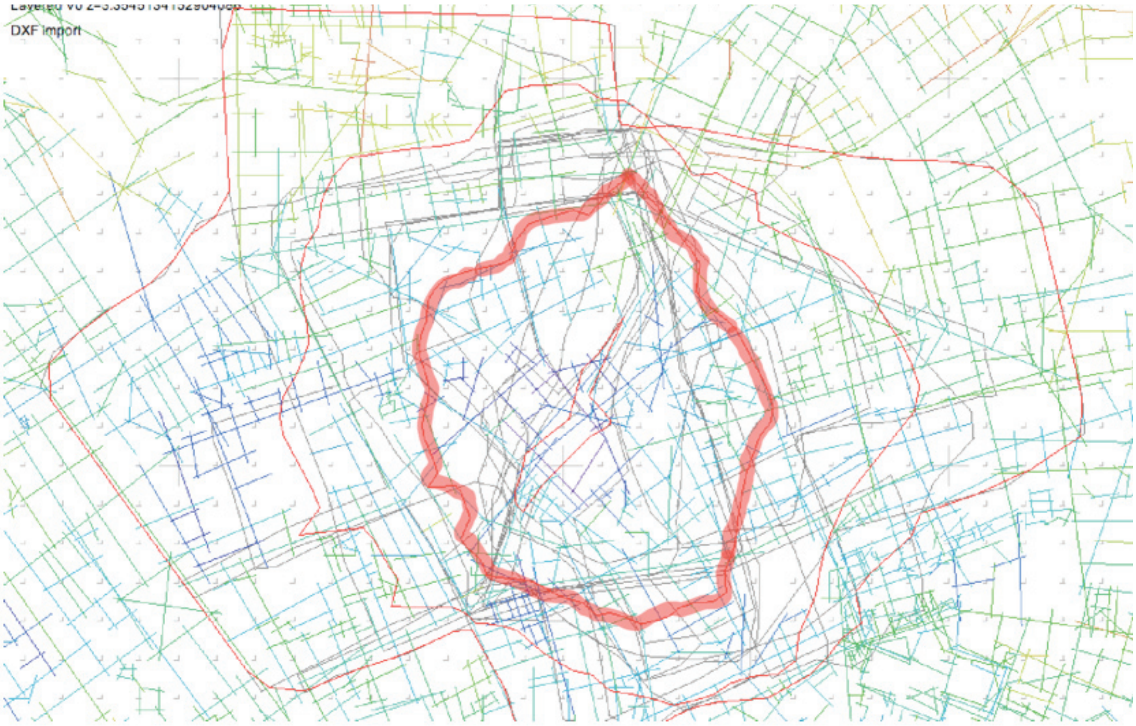


Figure 10.55 Average (consensus) neighbourhood for All Clerkenwell.

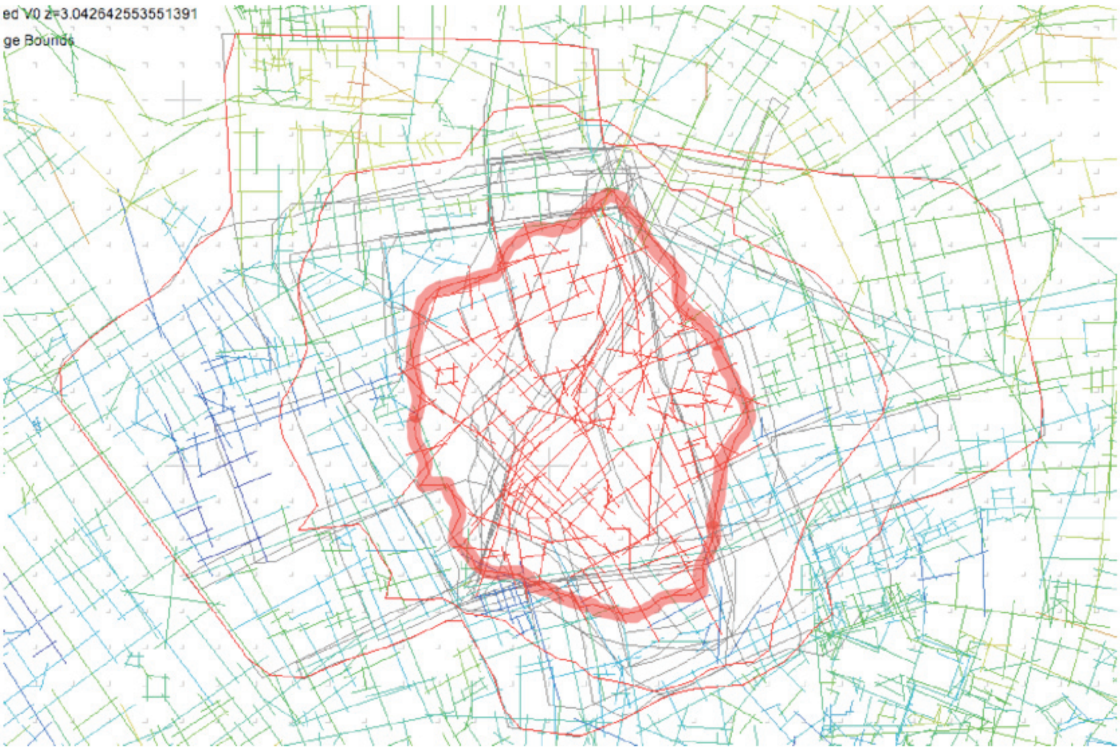


Figure 10.56 Average (consensus) neighbourhood results for respondents indicating all of Clerkenwell.

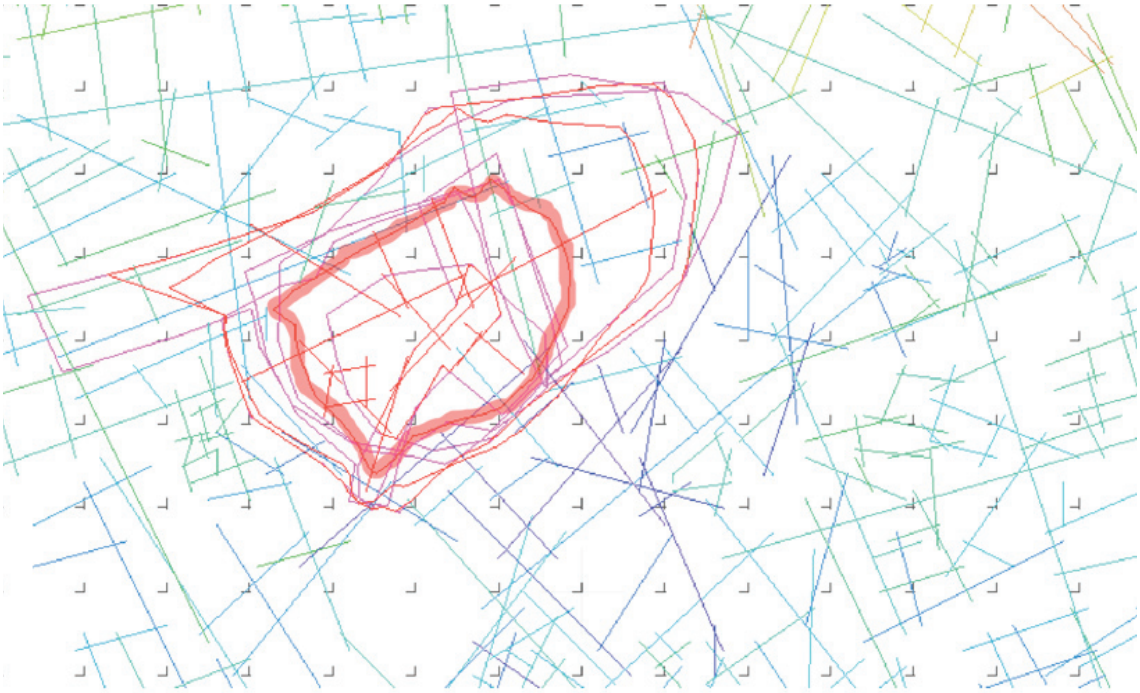


Figure 10.57 Average (consensus) neighbourhood results for respondents indicating Amwell or Village or clearly in bounds. Red lines indicate other selections at Point Intelligibility V = 65.

Figure 10.58 Average (consensus) neighbourhood for northern wing in bold red line.

measures become simply the traditional measure of intelligibility and synergy for the entire system, and we would expect a singular value for all axial lines. Thus, we may attribute the large constant area to having too small a map for the vicinity. This lack of neighbourhood scale differentiation then explains why the point synergy significance for V = 180, R = 4 for the consensus neighbourhood has a comparatively low value of 2.933.

Amwell Village

Beginning with Amwell/the Village/Unknown, we see in Fig. 10.57 both the consensus neighbourhood boundary and the lines selected in red. It would be tempting to suggest that the areas returned reflect those of the newly formed Amwell Village residents association, but it would be hard to maintain this hypothesis were it not for those who returned the same general area and gave no label or put 'unknown'.

The results for vicinity given in Table 10.11 Results for Amwell Village show that both point intelligibility and point synergy were given high levels of significance for the Z test (–5.939 and –15.11 respectively), while the value for point synergy V = 180, R = 3 is very low, showing that the area is simply within a larger area, as one would expect. We can draw the conclusion from this test that the area called 'Amwell/Village' does appear to be a non-random sample from the point synergy data. Visual inspection shows that the consensus neighbourhood does appear to be a zone of continuous point synergy and point intelligibility and that it is differentiated from the surrounding area. Thus, we can conclude that there is evidence present that is consistent with the statement that zones of continuous point intelligibility and point synergy appear to shadow the areas that residents are returning as a shared consensus neighbourhood.

Turning to the area around Exmouth market, we see that the respondents can be grouped into two principal zones, those north of Rosebury Avenue, as seen in Fig. 10.35 above, and those to the south. The theory is proposed that the north/south area is split by a small band (two streets) of a slightly different value of intelligibility, which is enough to mutually limit both the northern and southern neighbourhoods, but that the area also possesses both a strong local integrator and a local shopping area (Exmouth Market). Thus, the neighbourhoods form a butterfly with the wings representing the neighbourhoods and the body representing the separator streets, Rosebury Avenue and Exmouth Market/Myddelton St.

Exmouth Market Northern Wing

Fig. 10.58 shows the consensus neighbourhood in red and the axial lines that have been chosen. Table 10.12 shows the statistical results for the Z test for the selected area against the intersect values of point intelligibility and point synergy. This shows a strong statistical significance for point intelligibility (Z = –13.34) and point synergy (Z = 19.740) at vicinity V = 90, and no significant value for point synergy V = 180, R = 4 (Z = 0.166). This is consistent with the hypothesis that the point synergy and point intelligibility are not random samples from the general population.

Exmouth Market Southern Wing

Turning to Fig. 10.59, we see in red the consensus neighbourhood for those reporting

	Intelligibility	Point Synergy	Point Synergy
Vicinity	90	90	180
Radius		3	4
Neb Average	0.571	0.747	0.651
Neb N	59	59	59
Neb Stdev	0.097	0.069	0.007
All Average	0.402	0.588	0.643
N all	4718	4718	4718
All Stdev	0.120	0.569	0.018
Significance	-13.340	-19.740	0.166

Table 10.12 Northern wing.

	Point Intelligibility	Point Synergy	Point Synergy
Vicinity	90	90	180
Radius		3	4
Neb Average	0.538869105		
Neb N	70	55	55
Neb Stdev	0.075797876	0.072	0.007
All Average	0.401776566	0.569	0.651
N all	4718	4718	4718
All Stdev	0.120209876	0.146	0.018
Significance	-15.13233015	-19.674	3.334

Table 10.13 Southern wing.

	Intelligibility	Point Synergy	Point Synergy
Vicinity	90	90	180
Radius		3	4
Neb Average	0.582	0.759	0.648
Neb N	55	55	55
Neb Stdev	0.091	0.072	0.007
All Average	0.402	0.569	0.651
N all	4718	4718	4718
All Stdev	0.120	0.146	0.018
Significance	-14.631	-19.674	3.334

Table 10.14 North and South results.

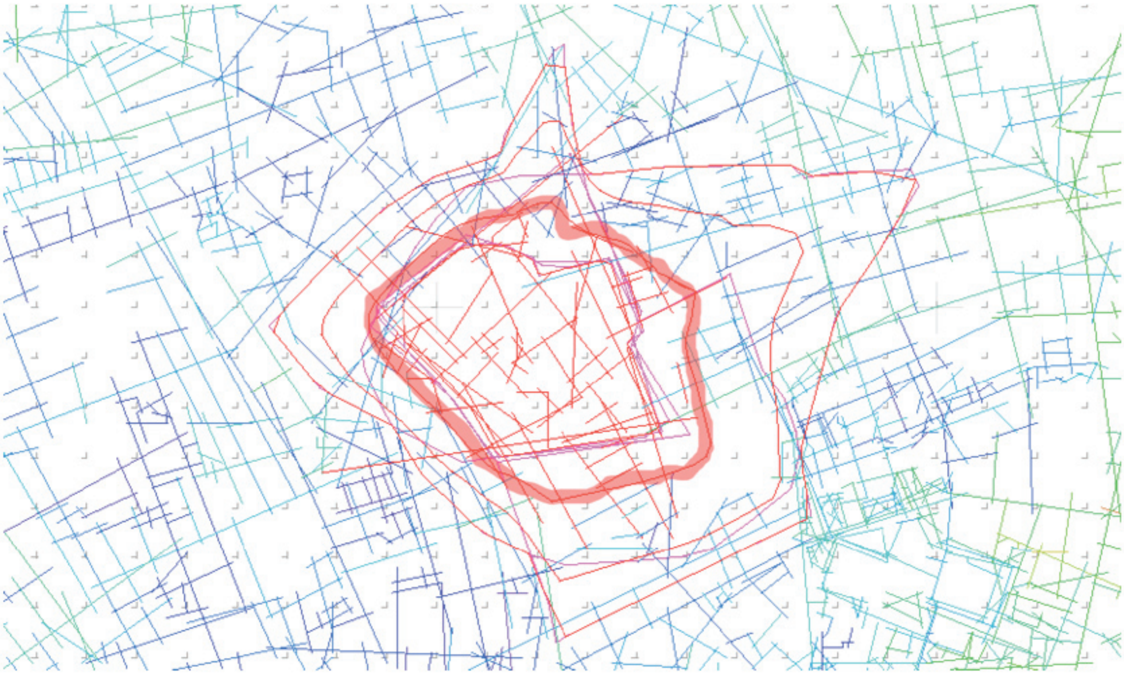


Figure 10.59 Average (consensus) neighbourhood for southern wing.

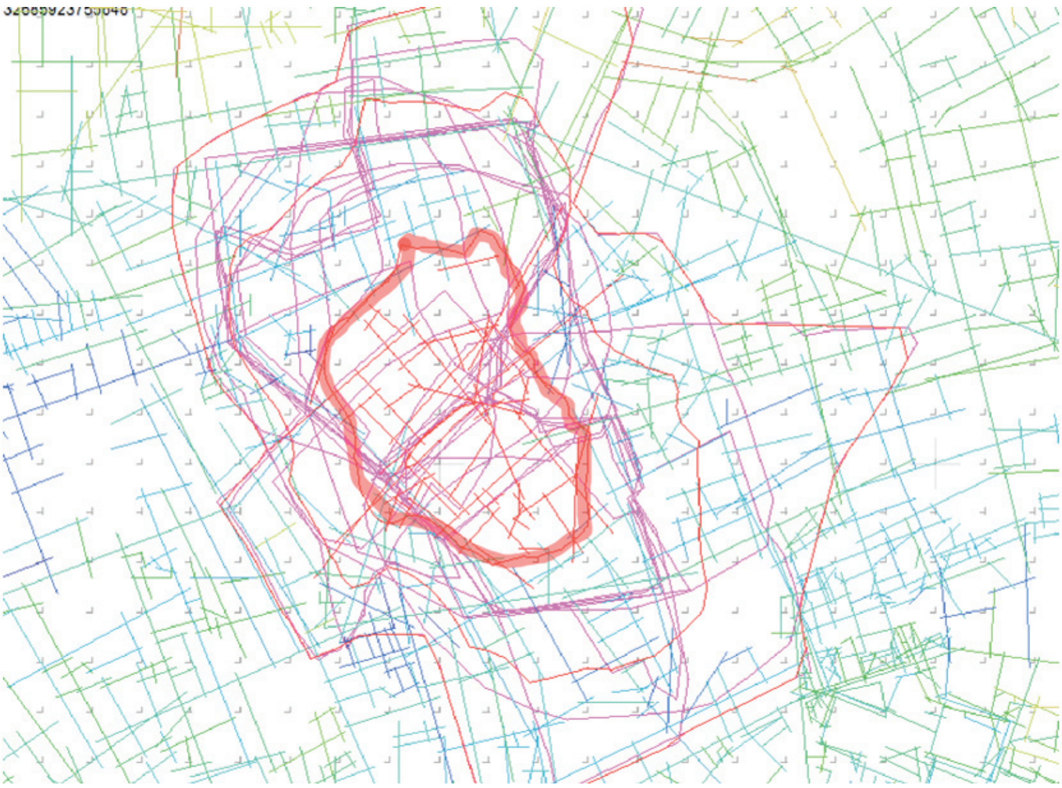


Figure 10.60 Average (consensus) neighbourhood for both wings + combination.

neighbourhoods south of the body of Exmouth Market. The red lines show those lines included in the statistical sample. Turning to the Table 10.13 results for the southern wing, we see that, like the area to the north, we have a strong Z test result for the significance of the non-random sample, with values of significance for point intelligibility and point synergy of 15.13 and –19.6, respectively. The value for point synergy V = 180, R = 4 is also above the level of random but is consistent with the visual observation that this encloses a wider area. This is consistent with the hypothesis that the point synergy and point intelligibility are not random samples from the general population.

Both wings and north south combination

Finally, there were three respondents that returned what looked to be both wings of the butterfly. One reported that they lived in the northern wing and worked in the southern, which might suggest an explanation for those reporting the larger area. It was thought that using such a small and diverse sample would not reproduce a valid consensus boundary but that it might be informative to combine both north and south wings to produce a combined consensus boundary. By doing this, we get the consensus boundary shown in red in Fig. 10.60, with the selected axial lines in red. The intersection with the underlying values gives Table 10.14. We see that the north and south wings have a strong Z test result for the significance of the non-random sample, with values of significance for point intelligibility and point synergy of –14.631 and –19.67, respectively. The value for point synergy V = 180, R = 4 (3.334) is also above the level of random, but is consistent with the visual observation that this encloses a wider area.

Chi-Squared statistical test for Link based agglomerative hierarchical clustering

The agglomerative hierarchical clustering method mentioned above of finding 128 clusters of near continuous values was repeated and the values, including the chi-squared values, are presented in table 10.15 below. As presented above, the simple average consensus boundary method was chosen for consistency with the previous results.

In the case of Clerkenwell, the lowest value was average integration, which had a score

Method	Chi squared	p-value	True, Positive	False, Positive	False, Negative	True, Negative
Point_ Synergy R_4_V180	1552.71	< 2.2e-16	62	110	3	4543
Point_Intel_ V180	935.3887	< 2.2e-16	46	126	12	4534
EMD=6	968.4585	< 2.2e-16	42	130	5	4541
Average Integration	403.1912	< 2.2e-16	67	106	178	4367
Orientation	526.7768	< 2.2e-16	48	128	55	4487
Random	545.1689	< 2.2e-16	54	118	74	4472

Table 10.15 Comparison of neighbourhood find methods for Clerkenwell.

lower than that of the random measure. The orientation method also scored worse in this historic and urban situation, suggesting that the aspect measured by these methods is not indicating the neighbourhood in this context. Since average integration was only proposed as a method for Dutch cities, this cannot be seen as a failure of the method. Equally, since orientation was given in the context of an American city, its failure in this unplanned context should not be regarded as a failure, but as a warning about overextending the method. Point intelligibility with a vicinity of 180 and EMD 6 gave chi-squared values that were twice that of randomness, suggesting that in this context they were both identifying something about the environment. Finally, point synergy, with radius 4 and vicinity 180, gave the highest value, which was nearly three times that of the randomness value.

It can be observed in all cases that the methods are all reporting areas that are larger than those of the actual neighbourhoods. In all of the cases, the false positives (lines claimed by each algorithm to be in the area that are not reported in the connected neighbourhood) outnumber the true positives and there are very few false negatives. While increasing the number of clusters should reduce the size of the neighbourhood and so make the number of false positives and false negatives drop, this was not the case in Clerkenwell.

This suggests that the structures of urban space and suburban space are different, which is a fruitful sign for future study but does not diminish the fact that point synergy appears to be reflecting the nature of the overall neighbourhood structure most strongly, with EMD also working consistently well.

Conclusions

In this chapter, two types of studies have been used to support the operational hypothesis that areas of constant point synergy appear to define one of the distinctive characteristics of a neighbourhood. It is clear from the initial survey of areas named by the Ordinance Survey that this appears to be a phenomenon that applies to a number of cities in the UK. The second series of empirical data collection exercises have demonstrated two things. First, when comparing the areas reported by respondents as their neighbourhoods, it is apparent that they lay on non-random samples of constant point intelligibility and constant point synergy. Secondly, by viewing the areas and sub-areas at different resolutions (via changes in the vicinity and radius parameters), it is apparent that different neighbourhoods are responding to different spatial structures.

In all of the cases presented, it was found that configuration had some relation to the neighbourhood boundaries reported by the residents. This was quite a significant finding, given that the inputs to the model were a pure representation of space and were comparable to the social impression of the location of the neighbourhood.

This chapter has presented some evidence that supports the view of Peponis that neighbourhoods can partially be defined by spaces or axial lines of strong choice, although it should be noted that this was not a universal result. This chapter has also suggested that the Read method of average radius cannot be applied to the English sample of data sets used.

The work presented on finding a consensus neighbourhood and comparing that to a neighbourhood reproducibly produced by link based agglomerative hierarchical clustering has shown that point synergy and EMD 6 appear to consistently achieve high chi-squared values compared to point intelligibility. The values of point synergy, EMD and point synergy also tend to outperform the average integration and orientation methods, which, while they can perform very well in a given context, do not perform as consistently well as the others. Nor do average integration and orientation consistently outperform the random aggregation comparison. The only method that consistently outperforms the randomness measure, and generally outperforms all of the other measures by a significant degree, is that of point synergy, suggesting that the extent of a neighbourhood is related to the nature of the local interplay between local structure and movement and global structure and movement.

We have seen that it is possible to extend the work of Hillier (Hillier 1996) on synergy and intelligibility to provide a mechanism that can be used to find, rather than test, neighbourhoods. This empirical work provides evidence for half of the place hypothesis, that places, or more specifically neighbourhood-places, are areas that have a continuous spatial character internally and that this character is unique and differentiates them from surrounding neighbourhoods.

Key points

Three neighbourhoods, Hampstead Garden Suburb (H.G.S), Brentham Garden Suburb (B.G.S), and an area near the city of London known as Clerkenwell, were studied.

Each area was processed with a number of neighbourhood finding methods.

Each area was also surveyed to discover the average for all the reported individual boundaries.

Using methods from the previous chapter a comparison between the reported boundary and the extends of the computed neighbourhood was performed.

In each case, a sample was found by Z test to be a non-random sample of lines reinforcing the visual inspection, which suggests that point intelligibility and point synergy are identifying natural or potential neighbourhoods in an urban environment.

After comparing point synergy and point intelligibility with a number of other methods, it was found that point synergy performed more consistently and generally more accurately than the other methods, and always performed better than the randomness test.

Chapter 11:
Summary and Conclusions

Summary

This chapter reviews the basic argument of the thesis, the question about the existence of a relation between space and place. This question was transformed into a more tractable and specific question involving the identification of the extent and textures of places via global spatial homogeneity and local spatial heterogeneity. Via a series of methodological and empirical innovations, data is presented that supports the argument that there is a spatial aspect of place that can be observed.

From this the conclusion is drawn that the null hypothesis that the absence of the relation between space and neighbourhood-place has been brought sharply into question. The chapter continues to show that the evidence presented has shown that aspects of place can be both identified experimentally and that aspects of spatial local heterogeneity (via revelation) and global homogeneity (via point synergy) reflect in our notion of place. The place hypothesis has been upheld to the extent that place is both empirically observable and partly based in space.

Thesis Summary

In the introduction, the thesis began with the observation that the human population is becoming increasingly urbanised, and that while more of the population is living in urban conditions, these urban conditions have been criticised by such thinkers as Nairn, Aug, Tzonis, Brampton, Rae, Tuan and Relph as 'placeless'. This criticism then raises the question about what place is and whether aspects of physical design can give rise to or act to extinguish place.

The literature review in chapter 2 began by surveying some of the notions of place and placelessness. These have been a motivation for the study of place from a phenomenological approach in human geography and have motivated movements to reinvigorate architectural and urban design, such as the New Urbanist movement in the US and the slow cities movement in Europe and the urban village movement in the UK. The literature review went on to show that the notion of place is a historic one reaching back to Aristotle and Plato, and showed that place is typically illuminated and deconstructed by the separation between the physical process of location and the social process of place. This separation has been reiterated in many ways, such as Leferbv's notion of first and second spaces or Tuan's separation between space and 'place'.

The chapter paused to review the meaning of terms such as place, space and location, suggesting that there might be some confusion when looking at place and space from an architectural background. The incertitude caused by the differing meanings for space in architecture and geography was noted and the definitions for the terms used in this thesis were given;

Space is used in the architectural sense of space. Place is used in the phenomenological use of place as a region of space to which there is some emotional response or attachment. Location is used in the phenomenological/mathematical sense of space, representing a position in Cartesian coordinates. The philosopher Susanne Langer introduced a debate that has been continuing in the study of place, related to whether there is a connection between location and place. Langer introduced a useful thought experiment involving place in a ship or camp to show that location is not the basis for place and that there is no necessary direct connection between the two. While there have been a number of arguments on both sides, this is a debate that is still unresolved. From a design point of view, the notion of place becomes more clearly discussed in the context of neighbourhood. While neighbourhood is one type of place, it does appear to simplify the rich concept of place down to a more tractable one. It is this notion of neighbourhood-place that became central to this thesis and any findings about place are not more general than this notion of neighbourhood-place.

The architect Norberg-Schultz introduced the notion of 'genus-loci', the spirit of a place, which is the idea that a place itself has a character or identity, to which one might become attached in the topophilia sense of the word. This raises the question: to what is one attached? The urban theorist Lynch introduced the term 'sense of place' to reflect this, and linked five elements that can be linked to events, experiences and mental representations, so forming a 'place identity.' Yet, from an operational sense, Lynch's five elements (path, node, districts, edges and landmarks) appear to be less objective and difficult to operationalise in design terms. Lynch's work in imagining, a property that he felt to be important to the sense of place was challenged by the architectural theorists Hillier and Hanson with a theory that came to be called space syntax. Hillier's first contribution was the notion that space was sufficient in and of itself to understand much about the function of a building or urban area in social terms. Returning to the place vs. location debate, it can be seen that Langer's thought experiment using a camp as a place was not as independent of the space of the camp as it was the location of the camp. This shifts the debate from location and place to space and place.

Using a purely mathematical model of space, Hillier substitutes 'intelligibility' for Lynch's legibility and introduces a new model of how the local structure of space is linked to the global structure via a measure he introduces called synergy. Thus, it seems logical to attempt to explore the notion of intelligibility and synergy in relation to place and neighbourhood. The chapter continued with a review of previous work done in the field of space syntax and phenomenology, and showed that there have been a number of calls from the space syntax field and from phenomenologists, such as David Seamon, for further research on place in space syntax. The chapter then concluded with a review of previous work done on neighbourhood or area approaches in space syntax and observed that these previous approaches were not concerned with the notion of place directly, and further that no previous approach has introduced objective empirical data to test a theoretical model.

Chapter 3 began by returning to the work of Norberg-Schultz, and from this work set two fundamental conditions for an experience based notion of place (that is a place that could be sensed of itself).

Place is hypothesised to be based on two fundamental aspects.

Homogeneity: That a place must have some continuity of character that would lead one to associate a set of locations (or a set of spaces) with one 'place'.

Heterogeneity: We must experience some local variation within that continuity to give the place the kind of character that differentiates one place from another.

To one extent if we accept that the homogeneity of an urban environment emerges from synergy then the notion of heterogeneity (local variance) is necessary to create synergy and is so an inherent property of it.

Without these fundamental aspects, it was argued that the character of a place would be indistinguishable from other places, or it would be impossible to notice a location as a separate entity.

Returning to the notions of space syntax, it was argued that space is an a priori concept that underlies our perceptions of place. That is, while some, such as Montello (Montello 2007), have criticised spatial approaches as ignoring the visual aspects, it is this very generalisation that appears to lead to many different ways of sensing the world around us as one thing (place). The chapter went on to argue that the homogeneity factor could be inferred using global knowledge, such as intelligibility or synergy. The heterogeneity could be matched by changes in the local visual field, such as via revelation. Alternatively as was reviewed in the literature review Penn (Penn 2001) suggested that one cognitive model was that people acted like 'correlation detectors' using the slope of the local synergy relationship to understand global as well as local changes. This approach would suggest that local changes were necessary to create the steep slope of the local/global integration graph).

This led to the hypothesis that neighbourhood place is based on two factors.

Neighbourhood place is an expression of global continuity and the unique identities of spaces.

At the same time, this is matched by an absence of local continuity in the spatial visual field, such as measured by (but not necessarily limited to) revelation.

Chapter 4 was an introduction to space syntax theory, relevant to this thesis. Specifically, it introduced isovists and gridded isovist analysis, and showed how axial maps can be made to model urban spaces. The notion of radius was explained in some detail as an introduction to the basis of the integration function, and some of the sophistication of the relativisation equations was demonstrated. The choice (axial betweenness) measure was explained, as was fractional angular integration, leading to segmental angular analysis.

One crucial observation made by this chapter was that relativisation equations cannot be applied to situations using weighted graphs. Three alternatives (Vicinity, Decay, Gaussian decay) were introduced to the radius relativisation process and their relative merits were discussed. The strong similarity between vicinity and relativisation was demonstrated.

Finally, the mathematical definitions for intelligibility (the vector product of the connectivities and integration values of a set of nodes in a graph) and synergy (the vector product of the local and global integration values of a set of nodes in a graph) were introduced. It was observed that, given the fact that local integration depends upon the outlined relativisation processes, it was currently impossible to compute synergy and intelligibility fairly for a segmental or angular axial map. This was an important point to make, as it limited this thesis to the use of axial representations in order to use synergy and intelligibility.

Chapter 5, the introduction to revelation theory, began with the second part of the place hypothesis, trying to determine what makes a location unique. It was noted that the environmental psychologists Kaplan and Kaplan theorised that there was a matrix of four states, coherence (immediate understanding), complexity (immediate exploration), legibility (inferred understanding) and mystery (inferred exploration), and they suggested that these four states are predictors of environmental preferences. Franz and Wiener also suggested that our embodied perception of the world around us could be usefully captured by considering certain aspects of our locally perceived space known as an isovist. They suggested that it was our ability to move through the environment (strongly related to the Kaplan concept of mystery) that was the key to what made a location 'interesting'. This they embodied in the measure of revelation, the total change in the area of the isovist field when moving from one point to all of the other surrounding points. While not publicly published on the matter, Benedict (Benedict 2000) also had the similar notion of 'new space'.

The chapter went on to discuss the notion of the computation of a number of spatial measures and looked at the mathematical definition of revelation. The chapter introduced a new visualisation of revelation based on either a gridded isovist (Turner) or a new stochastic isovist grid. A new stochastic isovist grid was introduced to explore the nature of some of the apparent problems when dealing with a body sized (low resolution) grid in a complex setting.

From the visualisations, it was apparent that revelation proposed by Franz and Wiener appeared to have problems in a number of contexts. A new variant, s-revelation, was introduced to respond to these problems, with the original revelation given the term f-revelation when used. Along with this, a new vector field was introduced based on the notion of revelation gradients proposed by Benedict. A new visualisation of this revelation gradient was produced to suggest the potential movement flow of an agent concerned with maximising new visual knowledge (i.e. Kaplan and Kaplan's mystery). The chapter went on to show that revelation was not a property purely of isovists. Axial lines are also capable of having revelation-like calculations applied to them. The chapter introduced a new visualisation for axial revelation and went on to an empirical study by using a number of test configurations with both isovist and axial revelations that the two different types of revelation appeared to strongly correlate. This suggested that while isovist revelation picks up a lot of small scale changes in the visual field, axial revelation can be a proxy for this kind of spatial change.

Chapter 6 looked at revelation in specific environments, that is, it reported on experiments conducted with the intention of testing the measurements of revelation against the experience of place. The basis for this thesis was the techniques used by the environmental psychologists Kaplan and Kaplan, who presented images to subjects and had them evaluate their emotional responses to the environments shown in the images. While Stamps mentioned more than 20 journal articles reporting studies that used this technique, Heft criticised this methodology, taking a more ecological or Gibsonian view, that it was the movement through a space that leads to a better and stronger perception. In the architectural field, Brettel made progress by getting participants to evaluate their responses to videos of moving through space and found interesting relations between the participants' responses and a number of spatial measures.

Chapter 6 continued reporting on an experiment undertaken to reproduce this work using revelation as one of the measures. The experiment took two nearly identical buildings and animated a route through an open featureless black and white sketch based movie. Participants were asked to find the location for a new place - specifically a café. Given that a fixed path was used for all of the participants, it was possible to compute an exact path isovist (measuring the isovist along a path). It was then possible to compute the total revelation along the path, and it was found that participants found the path with higher cumulative revelation more preferable as a place.

The results of this experiment reinforced the work of both Brettel and Franz & Wiener, suggesting that there is a correlation between spatial preference and experience at the local level. This work also strengthens the argument of Franz &Wiener that revelation provides a critical aspect of this experience. From this work it is possible to see that revelation appears to be part of the process of giving a spatial region Norberg-Schulz's genius loci, the spirit or character of a region. This supports part of the place hypothesis, that the heterogeneity of the spatial visual field, such as is measured by revelation, does appear to be related to people's perception of a place.

Chapter 7 took the neighbourhood regions found in chapter 10 and applied axial revelation to them. This chapter reported that the axial revelation found matched the change from sub-urban to urban environments. While not a statistically large sample this reinforces the results of chapter 6 as to the applicability of revelation to the understanding of the character of an area.

Chapter 8 began by returning to the place hypothesis, the need for continuity of character. Spatially, the Hillier notions of intelligibility and synergy have a good pedigree as plausible mechanisms to act in this manner. The chapter looked at intelligibility and suggested that it appears to be useful to consider intelligibility as the dot product between the vectors of integration and connectivity for all of the axial lines in a system (or all the nodes in a graph). From this clarification, it is possible to consider the effects caused by the size of a system (extrinsic intelligibility) and the inherent complexity (intrinsic intelligibility). It was shown that intelligibility appears to decline in proportion to the 1/3 power of the dimension (size or node count) of the system; in a selection of cities, this explained 52% of the intelligibility found. From this, a new method was introduced, that of cumulatively adding the axial lines in a system to produce an intelligibility growth curve. This suggested that cities get more complex (drop in intelligibility) from a starting point of view, but do so at different rates. It appeared that synergy was not as dependant on the size of a system as intelligibility.

Hillier made an interesting observation that all of the lines within a named area appeared to have certain structural properties that were not apparent within a randomly selected area. Yet, this introduced a problem, given that the named area was selected from knowledge about the area in advance it cannot tell us about the extents of that neighbourhood.

The chapter went on to attempt to separate this process by creating point intelligibility. Point intelligibility is the process of selecting a starting point and finding a subset of the larger graph that is centred on that point. Initially, radius was used but, given the non-comparability of intelligibilities of different sizes demonstrated in the earlier chapter, a vicinity based measure was later introduced. Visualising this back on to the urban axial map it was observed that the regions of continuous intelligibility appeared to identify known neighbourhoods.

This process was repeated with synergy. Evidence was presented to show that the neighbourhood effect was not the result of the aggregation mechanism.

Evidence was also presented to show that the effect was not the inevitable process of the intersection of axial lines. This left two mechanisms that appeared to identify neighbourhoods, which depended upon the 'design' of the structure of the grid rather than the effects of pure geometry.

Chapter 9 introduced two methods by which neighbourhoods could be identified empirically. The first mechanism was a simple exploratory test to see whether the named neighbourhoods in an ordnance survey map were predicted by the presence of regions of constant intelligibility and synergy. The results of this test were favourable, but the process of collecting and displaying the neighbourhood names was unknown and failed to be a high standard for comparison.

The chapter went on to use the neighbourhood called Beacon Hill (in Boston MA) identified by Lynch from sketch maps he asked inhabitants to draw. This gave the clear extent of the neighbourhood region and showed that it was possible to identify both the region and subregions (front side and back side) by changing the vicinity parameter.

The chapter went on to extend the method that had been used by Lynch, Lee and Montello of asking people to sketch the limits of their neighbourhood on a map. This method was extended by giving out a postal map and identifying people's ability to read the map. New analytic techniques were introduced to turn the regions returned by the participants into a unified 'consensus' boundary. This boundary was then used as the gold standard in two tests. In the first test, a Z test confirmed that the axial lines with similar point synergy and point intelligibility values were not simply random selections. The second test was a chi-squared test against a number of other axial area finding mechanisms, including an axial version of embeddedness, average integration, global orientation and a null hypothesis of randomness.

Chapter 10 took the methods introduced in chapter 9 and applied them to three case studies. Clerkenwell, Hampstead Garden Suburb and Brentham Garden Suburb. The chapter showed the complexities of real data collection of neighbourhoods. The conclusion of this second experiment was that point synergy performed more accurately and more consistently than all of the other methods in a comparison of three neighbourhoods in London. The results of this empirical work were consistent with the assertion that point synergy appears to identify the extent of a neighbourhood and so provided evidence for the first part of the place hypothesis.

The place hypothesis

The initial hypothesis of this thesis was that space was a constituent of what made a 'place'. The place hypothesis suggested that this might appear in both global and local aspects. Specifically the place hypothesis was

Heterogeneity: We must experience some local variation within that continuity to give the place the kind of character that differentiates one place from another.

Homogeneity: That a place must have some continuity of character that would lead one to associate a set of locations (or a set of spaces) with one 'place'.

Heterogeneity and revelation

Beginning with Heterogeneity, the body of work of Kaplan and Kaplan and others in the field of environmental psychology strongly links our emotional response to visual qualities of coherence, complexity, legibility and mystery. This was extended to the spatial dimension with revelation by Franz and Wiener. Empirical testing presented in this thesis using Franz and Wiener's revelation confirmed the work of Brettel, allowing us to concluded that space is also a constituent of our local appreciation of place. This appears to confirm the heterogeneity condition of the hypothesis.

Homogeneity and point synergy

We have seen that Hillier's notion of 'natural boundary' first observed in the correlation between observed pedestrian movement and integration. Hillier then identified that this 'natural boundary' correlated well with named areas in London. Hillier went on to observe that synergy, the correlation between global and local integration had a consistent appearance in 'well formed' neighbourhoods. Something that many including Penn (Penn 2001) suggested was a constitute of a 'sense of place'.

This thesis extended this notion of synergy to introduce local synergy mapping (point synergy). What stood out of the maps of point synergy was that what appeared to be named areas of a city have constant values of point synergy across them.

By collecting empirical data from local in habitants it was possible to show that regions identified by synergy corresponded better then other testable methods to inhabitants reported neighbourhood extents. It would be highly unlikely for this kind of correspondence to appear by accident and the observations about the emergence of Amwell village reinforce the connection between spacial configuration and neighbourhood extent. This appears to confirm the homogeneity condition of the hypothesis.

The resolution of the place hypothesis

Given that empirical work has upheld both the local heterogeneity and global homogeneity aspects of the hypothesis it seems reasonable to conclude that the thesis has succeeded in providing evidence to support the hypothesis that space is a constituent for place.

It should be remembered that what is claimed is that configuration of space is only part of the place puzzle. By the definitions used in this thesis place is the affective response to ones environment. Place as explored by Tuan and Relph a much broader spectrum of possible conditions which haven't been addressed given the empirical nature of the thesis. Importantly it is been demonstrated that space (rather than location) cannot be dismissed without addressing some of the evidence and theory that has been presented in this thesis.

Finally one of the objectives of this thesis was to create phenomenologically grounded research but exploring these ideas in an scientific and empirical way. The results of the thesis appear to reinforce commentators such as Semon and Hillier as to the possible synergy between these approaches.

Neighbourhoods and point synergy mapping

The Point synergy mapping that has emerged from the place hypothesis is the most surprising and powerful idea to emerge from this thesis. In retrospect the notion of synergy found in an area of an axial map is related to named areas was present in much of the work by Hillier in the 1990's and should not be as astonishing as it is. From a graph theoretic point of view it is already possible to apply an algorithm to a social network and derive social groupings and so the notion it might be possible to take a graph and find real social neighbourhoods should come as no surprise.

Alternatively thinking that it is possible to take a simple map of space and possibly identify the social property called neighbourhoods does appear astonishing. Just as early space syntax failed to need origin-destination matrixes to predict likely pedestrian and vehicular movement, point synergy mapping appears to only require an accurate axial map of space to give a strong indication of where neighbourhoods extend. As Penn (Penn 2001) stated it is this very parsimony of the axial map and synergy which could be said to lay at the heart of the very efficacy of the method.

This thesis has presented both the algorithm to process point synergy and as importantly reported on methods to test the resulting point synergy maps against the reality of the social perception of neighbourhood. If the algorithms and methods presented are reproduced in other cities and the outcome equally confirmed to the same extent that integration to pedestrian correspondence has been done in space syntax, then point synergy may also be a tool to elucidate the neighbourhood properties of an urban area. This may well had a direct usage in urban design giving designers insight into the outcomes of decisions in the early planing process. The technique of point synergy might also facilitate those such as urban archeologies looking to understand the neighbourhood structure of ancient urban environments from their remains.

A second observation for design comes from understanding that the Hillier notion of synergy is about relating the larger structure to the local structure of space. Thus, while we might think that creating a segregated area is a formula for creating neighbourhood. By following the roots of synergy we can see that it is the very absence of walls and barriers that is at the heart of creating neighbourhood reinforcing the thoughts of those such as Jane Jacobs. From an understanding of how synergy works, we can see that creating a walled community is in fact more akin to making a ghetto than a neighbourhood. This is equally true when creating total connectivity and uniformity; the absence of subtle waves in the fabric of urban space appears to prevent the foothold for difference and identity upon which place seems to depend.

Like point synergy mapping, in early syntax the emergence of integration correlating with observed movement was an unanticipated confirmation of theoretical advances. After the initial confirmation, it took time to develop sophistication in the understanding of the subtleties of an integration map and it is likely that this will be true with point synergy mapping.

One example of these subtleties we could see from studying the axial point synergy maps, not every region of constant synergy was known as a named place. Yet, as we saw from the data on Amwell village, a very local place that was identifiable on the synergy map was emerging as a place while the survey was being carried out. Some respondents in the survey felt that it was a place, even if the place had no name, while others had associated 'Amwell village' as a term for it. From this, it seems natural to suggest that the neighbourhoods defined by point synergy appear to be 'affording' (to use the Gibsonian term) the possibility for a neighbourhood. While the continuity or homogeneity of spatial structure does not 'cause' neighbourhoods, it does allow inhabitants every day lived activity to give rise to the social aspects of neighbourhood and so place. This argument is highly parallel with the notion of Hillier's 'natural movement', that what we observe in the integration maps are not causes of the movement but the natural influence of movement without any effect from a program. Equally, the synergy maps appear to be a visualisation of where neighbourhoods might naturally form ('natural neighbourhoods') without strong programmatic intervention.

As mentioned in both the introduction and the literature review many since the days of Perry (and possibly before) architecture and urban design movements have sort to create neighbourhood as an outcome of the chosen design strategy. As reported in the literature review there has been an on going debated between those who seek to 'create' neighbourhoods[1] and those that suspect that this is not possible from the design realm. Interestingly if point synergy mapping does emerge as a universal aspect of neighbourhood then this will not only undermine those such as Talen(Talen 1999,Talen 2000) that reject the possibility of design intervention in neighbourhood. Urban design movements such as the New Urbanists

1. As mentioned it is unlikely that neighbourhood can be truly said to be caused by urban design but this thesis would support the assertion that it can be inhibited or afforded by space.

and the Urban Village movement also have a comparatively weak articulation of space relying more on a textural, material and visual aspects of a design. If space is truly a fundamental aspect of neighbourhood then the manipulation of these other visual aspects may emerge to have only a symbolic effect on the formation of neighbourhood[2] forcing them to re-evaluate their strategies.

If the work of this thesis has further confirmation then the design profession will be much closer to a consensus on whether design does exert an influence on neighbourhood formation. What has emerged from this research appears to be confirmation that design choices can affect the extent of or even existence of a neighbourhood. What has also emerged from this research are tools and methods which can help research existing neighbourhoods possibly more fully clarifying what interventions design can have on the neighbourhood-as-place process. If the existence of place and neighbourhood has a role in the human environment as Tuan, Relph and others suggest, the point synergy mapping method sends a message to planners and architects that design does have a role to play in neighbourhood formation and this should be am active concern in both planning and urban design.

Key points

The outline of the thesis is reiterated.

Many have critiqued modern developments as placeless, raising the question of what place is and how place might be related to location (the physical space).

While place may be unrelated to location, this does not therefore mean that it is unrelated to space.

From the work of Norberg-Schultz it might be useful to consider place as a response to the character of a location.

The place hypothesis is formulated to suggest that place is embodied in space and that this may be through the space syntax mediums of intelligibility, synergy and revelation.

Chapters 6 and 7 reinforce other research that revelation might be responsible for the local heterogeneity of space.

Chapter 10 strongly supports the notion that space affords a number of aspects to define the extents of a neighbourhood.

It is concluded that the notion that there is no relation between space and place has been brought into question. Further very strong evidence has been presented that a spatial aspect to places is a essential component.

The conclusion is drawn that while many have thought that neighbourhood can be assured through the separation between one neighbourhood and the next, the clarity of neighbourhood produced by synergy suggests that it is the very lack of boundaries that affords neighbourhood from space.

2. This thesis has not tested aspects of the visual environment so it cannot be excluded at this time that material qualities of buildings may have an effect on neighbourhood formation as those such as the new urbanists might claim.

Chapter 12: Further Work

Summary

This chapter examines the contribution to practice and knowledge, then goes on to review the thesis and makes recommendations for further work based on both place and the empirical methods and theories presented.

Contributions of this thesis to practice and knowledge

It seems logical to identify some of the contributions to the field, outside of the direct support for the thesis that space and place are related by the notion of spatial affordance. In the introduction, it was argued that what was needed was a method for understanding place in a way that is compatible with design practice and it is the objective of this section to synthesis the thesis in this light.

The primary result of this thesis is the a framework (the place hypothesis) confirming that place can be an area of research using the objective and empirical methods of space syntax.

The software tools that could facilitate an urban designer to understand the extent of place in an urban design context. By using the tools developed (specifically webmap@home), it would be possible to experiment with different designs and observe the effects that they might have on natural neighbourhood-places. As such, it would be good to match the initial motivation with the exploitation of this and other tools developed for further use by designers.

While the sketch mapping methods have been used before, the tools and numerical methods developed to find the consensus boundary may be useful as both design tools and methods for further architectural research.

The postal survey mechanism has also emerged as a useful tool in the process of understanding neighbourhood.

The new formulations of revelation have also contributed to knowledge in the area and with the new tools that could be exploited for further research.

The notion of revelation gradients appears to be useful and deserves further use in an attempt to understand the patterns of motion and transitioning. They might also be of further theoretical use in way finding research.

The unpacking of intelligibility into intrinsic and extrinsic components appears to have use in our understanding and use of intelligibility during design. By fixing the size component, intelligibility might provide a way of making differing designs comparable, much in the same way that the integration relativisation equations make two different integration patterns comparable.

Finally, this thesis has stood out as the product of grounding objective empirical research in the observations of a phenomenologically based study. This was the kind of research called for by both Hillier and Seamon from their respective disciplines, and it is hoped that this work has shown the utility of this call.

Further work

Revelation

The work on the revelation gradient (or new space gradient) was presented in the chapter on revelation. It would be fruitful to compare this to observed movement flows through real and virtual environments to establish whether agents do attempt to maximise revelation in novel environments.

The measures of revelation implicitly contain some mechanism for the change in visual field. Yet, it is fruitful to think of the possibility that an informational approach to variety in the environment might be rewarding. This would mirror the work of Stamp (Stamp) by basically applying Shannon's (Shannon and Weaver 1949) information theory as a means of measuring the degree of complexity and information veracity in an environment.

As mentioned in chapter eight, when looking at ludic environments, it is common to use three-dimensional space maximally. Currently, the revelation and isovist concepts do not make any allowance for areas that can be seen but not reached in the same line of sight. Nor does an isovist reveal the volume or three dimensions of space. From an analytic point of view, it would be necessary to introduce the equivalent of the tran-spatial super-link found in axial mapping software in order to perform a basic isovist analysis on all but the simplest worlds.

Experimental Revelation

Clearly, a conclusion was reached from the results of only one experiment. Therefore, it might be fruitful to experiment with attempting to verify revelation in a number of different ways, to establish a stronger linkage between place preference and revelation.

The basic mechanism of using an online web based set of videos was taken from Brettel (Brettel 2006) and reworked into a place based experimental format. The work itself mirrored the practice in experimental environmental psychology (based on the work of Kaplan) of presenting a number of static images and asking the participants to assess them based on the criteria given. It might be rewarding to back up the initial experimental mechanism by holding a number of more fixed experiments in more rigorous conditions - as would be the case in experimental environmental psychology - and then comparing the results of the two data sets. Is the rigorous selection and personal observation of paid participants statistically different in results from unpaid anonymous volunteers spending a few minutes working on an online experiment?

One criticism of the experimental results might be that the worlds presented were too uninformative to make strong conclusions of the revelation or mystery of the places given. A complex recreation of the revelation experiment would add different elements, such as sound, lighting and texture to an animation or a full ludic environment to assess to what extent their absence would substantively affect the locations chosen. To do this, a number of comparative tests between different conditions with a large number of subjects would need to be performed in order to assess the relative effects with enough statistical validity.

Postal Survey

As we saw in the chapter on the empirical assessment of neighbourhood data, both the concept of neighbourhood and the kinds of reporting of neighbourhood are not tasks that can be undertaken mechanically. This partly reflects the richness of the urban environment and the complexity and diversity of the concept of neighbourhood. The use of the postal survey has proved to be effective when attempting to interpret the concept of neighbourhood. Compared to the alternative - that of interviewing residents - one aspect it solves is the difficulty of removing from the sample being taken those who are trying to be helpful that might create a random zone in order to fill in the form, or those who have problems recognising and interpreting maps. The postal mechanism simplifies the process of carrying on a number of interviews, making it an effective technique for those interested in both specific neighbourhoods and the interpretation of neighbourhoods.

The postal survey was a mechanism applied to a number of neighbourhoods around London and was remarkable in the general consistency of responses. It should be applicable to the entire UK and possibly American and European settlements. Further work needs to be done to establish whether it is possible to get similarly consistent results in differing spatial, linguistic and cultural settings. One way of extending or refining the questions about neighbourhood would be to set a specific task that would implicitly frame the definition of neighbourhood that we wished to establish. For example, asking which streets one might invite for a neighbourhood party might be a more concrete method than asking about 'the part of the city in which you live', the definition that was used from the Talyor (Taylor, Gottfredson et al.) methodology. Alternatively, it might be possible to ask the question in the negative and give a sample of streets (with possibly reference to a map), asking about which are either in or out of the neighbourhood. It might also be useful for comparative purposes to get non-inhabitants to report either their impression of where the neighbourhood lay (hence, seeing if it was possible to 'read' the neighbourhood consistency immediately without inhabitation) or asking those non-inhabitants to look at an unvisited neighbourhood to establish that the areas reported by the real inhabitants were different. It might be useful to augment the neighbourhoods reported on the map with the social neighbourhoods. For example, one might like to invite respondents to identify on the map where their neighbours, and those they consider within walking distance, are roughly located. This would require more sophisticated ethical approval but would give a stronger indication of the relationship between the social and territorial neighbourhoods. An alternative would be to get inhabitants to mark off all the facilities (shops, libraries, cafés, etc.) that they consider to be in their neighbourhood.

In terms of the survey questions, it is apparent that it is possible to respond to the concept of neighbourhood in a number of ways. As such, it might be best to suggest a more specific task that needs to be performed, rather than just consider the notion of 'where you live'. There have been a number of suggestions for neighbourhoods and their formation, such as the neighbourhood under crisis. This can be seen in the ‘Not in my backyard’ effect, when the neighbourhood responds to an external threat. For example, it might be interesting (if unethical) to ask questions such as

> *‘If it was announced that they were planning to build a prison/drop in centre for drug addicts, or some other undesirable building, what boundary would you draw beyond which you would not regard it as in your neighbourhood?’*

Naturally this would tend to emphasise the more personal boundary, as it would be natural not to put oneself at the edge of the boundary. As neighbourhood is still strongly reported in the sale of houses, it might be possible to ask a question such as

> *‘You meet Damian who proudly announces that he has moved into your neighbourhood at great expense. Can you draw the boundary of your neighbourhood beyond which you would think Damian has been a victim of estate agent sales speak?’*

The problem with this question is that it is in the negative and open to misinterpretation. Finally, one more direct question would be,

> *‘You have been given a fund to organise a party for your entire neighbourhood. Can you mark the streets or the boundary for the people that you would invite to such a party?’*

This question gives quite a direct and familiar task but it might limit the concept of neighbourhood to residential streets, and the interpretation of budget and organisational structure might lead to some residents limiting the radius to something more manageable.

The question about the number of households known, while not directly useful, does raise the question of the social neighbourhood. For example, it might be useful to try to measure the social network by getting respondents to mark on their maps the streets where their neighbourhood friends live. The problem with this is if it is presented as a part of the neighbourhood mapping mechanism it might alter the district drawn. There may also be ethical problems with reporting information about other people.

Consensus Neighbourhood

One of the most significant problems approached in chapter 8 is the task of building a consensus neighbourhood from the reported neighbourhoods and then testing that neighbourhood against that implied by the region of continuity of point intelligibility. Further work needs to be done to refine the construction of the consensus neighbourhood. Currently, the averaging mechanism is good at producing a single value, but in places it is apparent that some outliers are shifting the average unduly. It is also apparent in some cases, when a strong integrator acting as a partition is present, that the average value does not reflect the general consensus given by a number of respondents. Using an alternative averaging mechanism might give greater definition in these circumstances.

The area consensus mechanism was clearly not perfect, with the average being sometimes thrown off by a more extreme boundary reported by one respondent. There were a number of cases where a strong movement boundary was clearly the general consensus but the averaging mechanism was not accurately reflecting this process. Further work needs to be done to refine this mechanism.

The mechanisms for comparison between spatial continuity and reported consensus neighbourhood should be considered preliminary mechanisms, with more work being required to refine a stronger mathematical understanding of how the comparisons could be made at a statistical level. Clearly, more studies would also reinforce the statistical picture of the validity of the point synergy and point intelligibility mechanisms.

Neighbourhood Probability Density

The consensus neighbourhood method introduced in chapter 8 is functional but future work may bring about improvements.

An alternative mechanism to the consensus neighbourhood method would be to create a statistical test also be based on circumventing the use of the consensus neighbourhood altogether. Looking at the density maps (Fig. 8.63), we could imagine them as a probability that a point in space belongs to the neighbourhood, with low values to the outside and high probabilities to the centre. It is suggested that there is no true boundary but a steadily increasing likelihood toward the centre of the map (see Montello 2003). From this observation, we could assign each axial line the probability that the line is inside the neighbourhood (1.0 for complete agreement to 0.0 for agreement that the line is outside). This would then have to be compared in some way to the point synergy value for the line with some kind of statistical test between the probability and the point synergy measure. Like most tests, it is unclear how to statistically differentiate the values between lines. For example, if we imagine the neighbourhoods as circles and the areas of point synergy as circles, we have to account for the possibility that the neighbourhood circle might be considerably larger than the point synergy circle. The problem is that it is possible to have the smaller circle sit comfortably inside the larger circle, thus not reflecting the true comparability of boundaries. As mentioned, the process of comparison is also made more difficult by the presence of occasional long axial lines that can penetrate a number of areas, and hence have values reflecting a number of different areas.

It was also felt that alternative approaches, such as assigning each line with a probability for whether it is within the neighbourhood based on the number of reported neighbourhood boundaries by which it was contained, might give a more accurate picture. However, the statistical mechanism for comparing the measured values, such as point synergy with the probability of an axial line being within a neighbourhood, has yet to be developed.

Axial angularity and segmental angularity

Two developments that were still in the formative stages at the beginning of this research were the use of Axial Angularity (Dalton) and segmental angularity (Peponis, Dalton et al. 2003; Turner, Hillier, Yang 2007). The point intelligibility and point synergy mechanisms, specifically in cases with very long axial lines such as Boston, appeared to be partially compromised. Clearly, a segmental system might give more differentiation down the length of the line, and so hopefully reduce the cases of an axial line of differing point intelligibility piercing a region of more constant point intelligibility. Yang and Hillier are both working on segmental methods for neighbourhoods, but through completely independent spatial mechanisms. The core of this thesis was that place was a factor in the conception of space; a mechanism that strongly suggested the use of intelligibility and synergy as being objective measures of space that had some explanative power, being based on a view of how humans understand their environment. At the beginning of this thesis, there was no published work showing that an improvement in the correlation between movement and segmental integration or axial angular integration had been established, and as such, it would have been untenable to base one theory on another untested theory. Subsequent to the framing of this thesis, more data sets have emerged, to the point where segmental analysis is more the current standard. Yet, even if it had been used, there has not yet been any complete comparative research on a segmental or axial angle for intelligibility and synergy. For example, it is not clear what the equivalent of radius three might mean in segmental terms, although the work on vicinity (Dalton) and decay (Dalton 2008) leads in this direction. This area is rapidly expanding and the work of Yang and Hillier may yet produce a higher resolution version of the neighbourhood mechanism.

It should be noted that the axial angular intelligibility was also calculated during the evaluation process and appeared to give slight improvements in the point axial intelligibility maps, but this work was not included given the angular foundations that would have had to have been established as a basis. Clearly, it would be rewarding to return to this definition of neighbourhood, given a suitable angular definition of intelligibility, and more importantly, synergy.

Key points

Key contributions to practice and knowledge were identified.

Further work to develop the theory and methodologies presented was suggested.

Chapter 13: References

Agnew, J.A., 1987. Place and politics: the geographical mediation of state and society.

Aldous, T., 1992. *Urban villages: a concept for creating mixed-use urban developments on a sustainable scale*, Urban Villages Group London.

Alexander, C. et al., 1977. *A pattern language*, Oxford Univ. Pr.

Appleyard, D., 1980. Livable Streets: Protected Neighborhoods? *The ANNALS of the American Academy of Political and Social Science*, 451(1), p.106.

Appleyard, D., 1981. *Liveable streets. Berkeley*, University of California Press.

Asami, Y. et al., 2003. Introducing the third dimension on Space Syntax: application on the historical Istanbul. In *Proceedings of the Fourth International Symposium on Space Syntax, University College London, London.*

Augé, M., 1995. *Non-places: Introduction to an Anthropology of Supermodernity*, Verso Books.

Benedikt, M.L., 1979. To take hold of space: isovists and isovist fields. *Environment and Planning B*, 6(1), pp.47–65.

Benedikt, M.L., 2000. Re: doctoral research, isovists, VR etc. private communication to Dalton,R.,C.

Blakely, E.J. & Snyder, M.G., 1997. Fortress America: gated communities in the United States. *Washington DC, Cambridge.*

Boerner, M. 2009. *More about the neighbourhood. Academic housing in London.* December 6. Available at: http://www22.homepage.villanova.edu/margaret.boerner/GPS/moreabout.htm.

Brettel, A., 2006. *The effects of "order" and "disorder" on human cognitive perception in navigating through urban environments.* Bartlett School of Architecture: University College London, Available at: http://eprints.ucl.ac.uk/2359/.

Buckley, F. & Harary, F., 1990. *Distance in graphs*, Addison-Wesley Reading, MA.

Buttimer, A. & Seamon, D., 1980. *The human experience of space and place*, Taylor & Francis.

CABE et al., 2004. The value of public space: how high quality parks and public spaces create economic, social and environmental value. Available at: http://www.cabe.org.uk/files/the-value-of-public-space.pdf.

Casey, E.S., 1993. *Getting back into place: Toward a renewed understanding of the place-world*, Indiana Univ Pr.

Clauset, A., Newman, M.E. & Moore, C., 2004. Finding community structure in very large networks. *Physical Review E*, 70(6), p.66111.

Conroy Dalton, R. & Dalton, N., 2001. Omnivista: An application for isovist field and path analysis. In *The Third Space Syntax Symposium*. Space Syntax-III International Symposium. Atlanta GA, pp. 25,28.

Conroy, R.A., 2001. *Spatial navigation in immersive virtual environments PhD thesis.* London: Bartlett School of Graduate Studies, University of London, Available at: http://www.thepurehands.org/phdpdf/thesis.pdf.

Couclelis, H., 1999. Space, time, geography. *Geographical Information Systems: Principles and Technical Issues*, 1, pp.29–38.

Cresswell, T., 2004. *Place: a short introduction*, Wiley-Blackwell.

Dalton, N., 2001. *WebmapAtHome(Software)*, Available at: http://homepage.mac.com/thesheep/FileSharing10.html.

Dalton, N., 2001. Fractional configurational analysis and a solution to the Manhattan problem. In *Space Syntax 3rd International Symposium, Atlanta.*

Dalton, N., 2003. Storing directionality in axial lines using complex node depths. In *Proceedings of the Fourth International Symposium on Space Syntax, University*

College London, London. Available at: http://www.spacesyntax.org/symposia/SSS4/fullpapers/63Daltonpaper.pdf.

Dalton, N., 2004. *Interstice (software)*, Ovinity. Available at: www.ovinity.co.uk/download/Interstice.html.

Dalton, N.S., 2005. New measures for local fractional angular integration or towards general relativisation in space syntax. In *5th International Space Syntax Symposium, Delft, Netherlands*.

Dalton, N.S.C., 2006. Configuration and Neighborhood: Is Place Measurable. In *Space Syntax and Spatial Cognition Workshop of the Spatial Cognition*.

Dalton, N., 2007. WebmapAtHome. Proceedings of Workshop on New developments in Space Syntax software. Available at: http://eprints.ucl.ac.uk/4109/1/4109.pdf.

Dalton, N. & Dalton, C., 2007. Applying depth decay functions to space syntax network graphs. In *Proceedings of the 6th International space syntax symposium*. Sixth International Space Syntax Symposium. Istanbul, p. 089. Available at: http://discovery.ucl.ac.uk/1113/1/1113.pdf.

Dalton, R. & Bafna, S., 2003. The syntactical image of the city: a reciprocal definition of spatial elements and spatial syntaxes. In *4th International Space Syntax Symposium*. 4th International Space Syntax Symposium. London. Available at: http://eprints.ucl.ac.uk/1104/01/SIC.pdf.pdf.

Downs, R.M. & Stea, D., 1973. Cognitive maps and spatial behavior: Process and products. *Image and environment: Cognitive mapping and spatial behavior*, pp.8–26.

Downs, R.M. & Stea, D., 1977. *Maps in minds: Reflections on cognitive mapping*, Harper & Row New York.

Figueiredo, L. & Amorim, L., 2005. Continuity lines in the axial system. In *Proceedings of the Fifth Space Syntax International Symposium*. pp. 13–17. Available at: http://www.spacesyntax.tudelft.nl/media/Long%20papers%20I/lucasfigueiredo.pdf.

Forty, A., 2000. *Words and buildings: a vocabulary of modern architecture*, Thames & Hudson. Available at: http://morfologia.arch.duth.gr/4o_etos/4o_exam_VIII/wb_form.pdf.

Frampton, K., 1985. Towards a critical regionalism: six points for an architecture of resistance. *Postmodern culture*, pp.16–30. Available at: http://www.colorado.edu/envd/courses/envd4114-001/Spring%2006/Theory/Frampton.pdf.

Franklin, B. & Tait, M., 2002. Constructing an image: the urban village concept in the UK. *Planning Theory*, 1(3), p.250.

Franz, G. & Wiener, J.M., 2005. Exploring isovist-based correlates of spatial behavior and experience. In *Proceedings of the 5th International Space Syntax Symposium*. 5th International Space Syntax Symposium. Delft, NL.: TU Delft Press. Available at: http://www.spacesyntax.tudelft.nl/media/longpapers2/geraldfranz.pdf.

Freeman, L.C., 1977. A set of measures of centrality based on betweenness. *Sociometry*, 40(1), pp.35–41. Available at: http://moreno.ss.uci.edu/23.pdf.

Freeman, L.C., 1979. Centrality in social networks conceptual clarification. *Social networks*, 1(3), pp.215–239. Available at: http://www.soc.ucsb.edu/faculty/friedkin/Syllabi/Soc148MA/Freeman78.PDF.

Fuchigami & Masayuki, 1993. Architect on the Scene. *Kenchiku Bunka Magazine*, pp.12-13.

Fund United Nations Population, Martine, G. & Marshall, A., 2007. State of world population 2007: unleashing the potential of urban growth.

Gibson, J.J., 1986. *The ecological approach to visual perception*, Lawrence Erlbaum.

Girvan, M. & Newman, M.E., 2002. Community structure in social and biological networks. *Proceedings of the National Academy of Sciences of the United States of America*, 99(12), p.7821.

Giuliani, M.V. & Feldman, R., 1993. Place attachment in a developmental and cultural context. *Journal of Environmental Psychology*, 13, pp.267–267.

Golledge, R., 1995. Path selection and route preference in human navigation: A progress report. *Spatial Information Theory A Theoretical Basis for GIS*, pp.207–222.

Golledge, R.G. & Rushton, G., 1976. *Spatial choice and spatial behavior*, Ohio State University Press.

Gould, P. & White, R., 2004. *Mental maps*, Routledge.

Greer, S.A., 1998. *The emerging city: Myth and reality*, Transaction Pub.

Guest, A.M. & Lee, B.A., 1984. How urbanites define their neighborhoods. *Population & Environment*, 7(1), pp.32–56.

Hanson, J. & Hillier, B., 1987. The architecture of community: some new proposals on the social consequences of architectural and planning decisions. *Architecture et Comportement/Architecture and Behaviour*, 3(3), pp.251–273. Available at: http://eprints.ucl.ac.uk/5265/1/5265.pdf.

Hanson, J., 1989. Order and structure in urban design: the plans for the rebuilding of London after the Great Fire of 1666. *Ekistics*, 56(334-335), pp.22–42.

Hanson, J.M., 1989. *Order and structure in urban space A morphological history of the City of London*. Phd. London: Bartlett School of Architecture and Planning , University College London.

Haq, S. & Zimring, C., 2003. Just Down The Road A Piece. *Environment and behavior*, 35(1), p.132. Available at: http://cool.coa.gatech.edu:8000/AdvReadings/uploads/haq_zimring%202003.pdf.

Harary, F., 1959. Status and contrastatus. *Sociometry*, 22(1), pp.23–43.

Hardy, A.C., 1967. Landscape and Human Perception. *Methods of Landscape Analysis*, 8(3).

Harrison, S. & Dourish, P., 1996. Re-place-ing space: the roles of place and space in collaborative systems. In *Proceedings of the 1996 ACM conference on Computer supported cooperative work*. pp. 67–76. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.94.6332&rep=rep1&type=pdf.

Heft, H., 1996. The ecological approach to navigation: A Gibsonian perspective. *The construction of cognitive maps*, pp.105–132.

Hillier, B. & Leaman, A., 1973. The man-environment paradigm and its paradoxes. *Architectural Design*, 78(8), pp.507–511.

Hillier, B. & Hanson, J., 1984. *The social logic of space*, Cambridge University Press Cambridge.

Hillier, B. & Hanson, J., 1987. The architecture of community: some new proposals on the social consequences of architectural and planning decisions. *Architecture et Comportement/Architecture and Behaviour*, 3(3), pp.251–273.

Hillier, B., 1988. Against enclosure. *Rehumanizing housing*, 2, pp.25–1.

Hillier, B. & Penn, A., 1991. Visible colleges: structure and randomness in the place of discovery. *Science in Context*, 4(01), pp.23–50.

Hillier, B. et al., 1993. Natural movement: or, configuration and attraction in urban pedestrian movement. *Environment and planning B*, 20(1), pp.29–66.

Hillier, B., 1996. *Space is the Machine*, Citeseer. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.137.7707&rep=rep1&type=pdf.

Hillier, B., 1999. Centrality as a process: accounting for attraction inequalities in deformed grids. *Urban Design International*, 4(3), pp.107–127.

Hillier, B., 2002. A theory of the city as object: or, how spatial laws mediate the social construction of urban space. *Urban Design International*, 7(3), pp.153–179. Available at: http://eprints.ucl.ac.uk/1029/01/hillier_city2001.pdf.

Hillier, B., 2005. Between social physics and phenomenology. In *5th International Space Syntax Symposium*. 5th International Space Syntax Symposium. Delft, pp. 3-23. Available at: http://eprints.ucl.ac.uk/1679/1/hillier05-socialphysics.pdf.

Hillier, B., 2005. The art of place and the science of space. *World Architecture*, 185, pp.96–102. Available at: http://eprints.ucl.ac.uk/archive/00001678/01/hillier05-artofspace-english.pdf.

Hillier, B. & Iida, S., 2005. Network and psychological effects in urban movement. *Spatial Information Theory*, pp.475–490.

Hillier, B. et al., 2007. Metric and topo-geometric properties of urban street networks. In *6th International Symposium on Space Syntax, ITU, Istanbul*. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.120.7077&rep=rep1&type=pdf.

Howard, E., 1898. Tomorrow, a Peaceful Path to Social Reform. *London, UK*.

Hu, M.K., 1962. Visual pattern recognition by moment invariants. *IEEE Trans on Information Theory*, 8(2), pp.179–187.

Hu, M.K., 2002. Visual pattern recognition by moment invariants. *Information Theory, IRE Transactions on*, 8(2), pp.179–187.

Hunter, A. & Janowitz, M., 1974. *Symbolic communities: The persistence and change of Chicago's local communities*, University of Chicago Press Chicago.

Huxford, R., 1998. Urban villages: an introduction. In *Proceedings of the Institution of Civil Engineers: Municipal Engineer*. pp. 204–6.

Jackson, K.T. & Dunbar, D.S., 2005. *Empire City: New York Through the Centuries*, Columbia Univ Pr.

Jacobs, J., 1961. The life and death of great American cities. *New York*.

Jowett, B., 1872. *The dialogues of Plato*, Herzberg Press.

Kant, I., 1933. *Immanuel Kant's Critique of Pure Reason, trans*, trans. Norman Kemp Smith.

Kaplan, S. & Kaplan, R., 1982. *Cognition and environment*, Praeger.

Kaplan, S., 1988. Perception and landscape: conceptions and misconceptions. *Environmental aesthetics: Theory, research, and application*, pp.45–55. Available at: http://www.fs.fed.us/psw/publications/documents/psw_gtr035/psw_gtr035_05_s-kaplan.pdf.

Katz, P., Scully, V.J. & Bressi, T.W., 1994. *The new urbanism: Toward an architecture of community*, McGraw-Hill Professional. Available at: http://ironwarrior.org/ARE/Pre_Design/The%20New%20Urbanism.doc.

Kernighan, B.W. & Lin, S., 1970. An efficient heuristic procedure for partitioning graphs. *Bell System Technical Journal*, 49(2), pp.291–307.

Kim, Y.O., 2001. The role of spatial configuration in spatial cognition. In *Proceedings of the Third International Space Syntax Symposium*. University of Michigan, Ann Arbor, MI: Taubman College of Architecture and Urban Planning, pp. 49.41-49.21.

Kim, Y.O. & Penn, A., 2004. Linking the spatial syntax of cognitive maps to the spatial syntax of the environment. *Environment and behavior*, 36(4), p.483.

Knox, P.L., 2005. Creating ordinary places: Slow cities in a fast world. *Journal of Urban Design*, 10(1), pp.1–11. Available at: http://210.74.184.3/international/case/case/390.pdf.

Kunstler, J.H., 1994. *The geography of nowhere: The rise and decline of America's man-made landscape*, Free Press.

Lakoff, G., 1990. *Women, fire, and dangerous things*, Univ. of Chicago Press.

Langer, S.K., 1953. *Feeling and form.*, New York: Scribner.

Leccese, M. & McCormick, K., 2000. *Charter of the new urbanism*, McGraw-Hill Professional.

Lee, T., 1973. Psychology and living space. *Image and Environment: Cognitive Mapping and Spatial Behavior*, pp.87–108.

Lefaivre, L. & Tzonis, A., 2003. Critical Regionalism: Architecture and Identity in a Globalized World. *Prestel, New York, USA*.

Lefebvre, H., 1991. *The production of space*, Wiley-Blackwell.

Leman-Stefanovic, I. & Stefanovic, I.L., 2000. *Safeguarding our common future: Rethinking sustainable development*, State University of New York Press.

Low, S.M. & Altman, I., 1992. Place attachment: A conceptual inquiry. *Place attachment*, pp.1–12.

Lynch, K., 1954. The form of cities. *Scientific American*, 190(20), pp.54–63. Available at: http://www.isc.meiji.ac.jp/~cova/column/the_forms_of_cities.pdf.

Lynch, K., 1960. *The image of the city*, the MIT Press.

Lynch, K., 1981. *A theory of good city form*, MIT Press Cambridge, MA.

Lynch, K., 1985. The city as environment. *Mirrors of Mind: An Introduction to Humanities*, p.103.

Malpas, J.E., 1999. *Place and experience: A philosophical topography*, Cambridge Univ Pr.

Manzo, L.C. & Perkins, D.D., 2006. Finding common ground: The importance of place attachment to community participation and planning. *Journal of Planning Literature*, 20(4), p.335.

McClenahan, B.A., 1929. *The Changing Urban Neighborhood: From Neighbor to Nigh-dweller; a Sociological Study*, University of Southern California.

McGuigan,, M., 2005. Amwell Street: bags of atmosphere. *Telegraph*.

McKean, E., 2005. *The New Oxford American Dictionary*, Oxford University Press New York, NY:

McKenzie, R.D., 1921. The Neighborhood: A Study of Local Life in the City of Columbus, Ohio. I. *American Journal of Sociology*, 27(2), pp.145–168.

Miranda, A. & Chan, M., 2007. *Report on comparison of garden suburbs*, London: University College London Bartlett Graduate School.

Montello, D.R. et al., 2003. Where's downtown?: Behavioral methods for determining referents of vague spatial queries. *Spatial Cognition & Computation*, 3(2), pp.185–204.

Montello, D.R., 2007. The contribution of space syntax to a comprehensive theory of environmental psychology. In *Proceedings of 6th International Space Syntax Symposium*. 6th International Space Syntax Symposium. Istanbul, Turkey. Available at: http://www.spacesyntaxistanbul.itu.edu.tr/papers%5Cinvitedpapers%5Cdaniel_montello.pdf.

Mostafavi, M. & Leatherbarrow, D., 1993. *On weathering: the life of buildings in time*, The MIT Press.

Mottram, C. et al., 1999. Virtual Beings: Emergence of Population Level Movement and Stopping Behaviour from Indivual Rulesets.

Nairn, I., 1957. *Counter-attack against Subtopia*, Architectural press.

Neal, P., 2003. *Urban villages and the making of communities*, Taylor & Francis.

Newman, M.E., 2004. Detecting community structure in networks. *The European Physical Journal B-Condensed Matter and Complex Systems*, 38(2), pp.321–330. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.111.9493&rep=rep1&type=pdf.

Newman, O., 1996. *Creating defensible space*, Diane Pub Co.

Norberg-Schulz, C., 1971. *Existence, space & architecture*, Studio Vista London.

Norberg-Schulz, C., 1976. The Phenomenon of Place. *Architecture Association Quarterly*, 8(4), pp.3-10.

Norberg-Schulz, C., 1984. *Genius loci: Towards a phenomenology of architecture*, Rizzoli.

Norberg-Schulz, C., 1996. The Phenomenon of Place'(1976). *Theorizing a New Agenda for Architecture. An Anthology of Architectural Theory 1965–1995.*

Norberg-Schulz, C., 2003. The Phenomenon of place. *Designing cities: critical readings in urban design*, p.116.

Peatross, F.D., 2001. A syntactic study of control in restrictive settings: innovations in isovist methods. *Environment and Planning B*, 28(4), pp.529–544.

Peet, R., 1998. *Modern geographical thought*, Wiley-Blackwell.

Penn, A. et al., 1997. Intelligent architecture: new tools for the three dimensional analysis of space and built form.

Penn, A. & Croxford, B., 1998. Fingerprinting urban kerbside carbon monoxide concentrations: interaction between street grid configuration, vehicle flows and local wind effects. *International Journal of Vehicle Design*, 20(1), pp.60–70.

Penn, A. & Dalton, N., 1994. The architecture of society: stochastic simulation of. *Simulating societies: the computer simulation of social phenomena*, p.85.

Penn, A. et al., 1998. Configurational modelling of urban movement networks. *Environment and Planning B: planning and design*, 25(1), pp.59–84.

Penn, A., 2001. Space Syntax and Spatial Cognition. Or, why the axial line? In *3rd International Symposium on Space Syntax.* 3rd International Symposium on Space Syntax. Atlanta, GA, USA: Georgia Institute of Technology, pp. 11.1 - 11.16.

Penn, A., 2003. Space syntax and spatial cognition. *Environment and Behavior*, 35(1), p.30. Available at: http://eprints.ucl.ac.uk/3419/1/3419.pdf.

Penn, A. & Carvalho, R., 2004. Scaling and universality in the micro-structure of urban space. *Physica A: Statistical Mechanics and its Applications*, 332, pp.539–547. Available at: http://arxiv.org/pdf/condmat/0305164.

Peponis, J. et al., 1988. *Social structure of space and relations of community in six Greek cities*, Secretariat of Research and Technology, Athens, Ministry of Energy Industry, Research and technology.

Peponis, J., 1997. Geometries of Architectural Description. In *Space Syntax. First International Symposium Proceedings.* p. 34.

Peponis, J., Dalton, N.S. & Dalton, C., 2003. To tame a tiger one has to know its nature: extending weighted angular integration analysis to the description of GIS road-centerline data for large scale urban analysis. In *Proceedings of the 4th International Space Syntax Symposium.* London. Available at: http://eprints.ucl.ac.uk/1109/1/TTT.pdf.pdf.

Perdikogianni, I., 2007. FROM SPACE TO "PLACE". In The 6th Space Syntax Symposium. Istanbul, Turkey. Available at: http://www.spacesyntaxistanbul.itu.edu.tr/papers%5Clongpapers%5C052%20-%20Perdikogianni.pdf.

Perry, C., 1998. *The Neighbourhood Unit: From the Regional Survey of New York and Its Environs: Volume VII: Neighbourhood and Community Planning*, Routledge.

Perry, C., 2003. The neighborhood unit: Regional survey of New York and its environs. *VII, Committee on Regional Plan of New York and its Environs, New*, pp.22–140.

Pink, S., 2007. Sensing Cittàslow: slow living and the constitution of the sensory city. *The Senses and Society*, 2(1), pp.59–77.

Pothen, A., Simon, H.D. & Liou, K., 1990. Partitioning sparse matrices with eigenvectors of graphs. *SIAM Journal on Metrix Analysis and Applications;(United States)*, 11(3).

Radicchi, F. et al., 2004. Defining and identifying communities in networks. *Proceedings of the National Academy of Sciences of the United States of America*, 101(9), p.2658.

Rae, D.W., 2003. *City: Urbanism and its end*, Yale Univ Pr.

Raford, N., 2004. *Movement economies in fractured urban systems: the case of Boston, Massachusetts*. Bartlett School of Gradate Studies. London, University College London.

Raford, N. & Hillier, B., 2005. Correlation landscapes: a new approach to sub-area definition in low intelligibility spatial systems. In *Proceedings of the 5th Space Syntax Symposium*.

Read, S., 1999. Space syntax and the Dutch city. *Environment and Planning B*, 26, pp.251–264.

Read, S., 2001. Thick urban space: Shape, scale, and the articulation of the urban in an inner-city neighbourhood of Amsterdam. In *Proceedings, Space Syntax Symposium*.

Read, S. & Budiarto, L., 2003. Human scales: Understanding places of centring and de-centring. In *IV International Space Syntax Conference, London, University College London*.

Read, S., 2005. Flat City: A space syntax derived urban movement network model. In *Proceedings of the 5th Space Syntax Symposium*.

Reid, A., 2000. *Brentham: A History of the Pioneer Garden Suburb, 1901-2001*, Brentham Heritage Society.

Relph, E., 1976. *Place and placeness*, London: Pion.

Relph, E.C., 1981. *Rational landscapes and humanistic geography*, Rowman & Littlefield Publishers, Inc.

Romesburg, C., 2004. *Cluster analysis for researchers*, Lulu press.

Sailer, K. & Penn, A., 2007. The performance of space–exploring social and spatial phenomena of interaction patterns in an organisation. In *International Architecture and Phenomenology Conference*. International Architecture and Phenomenology Conference. Available at: http://discovery.ucl.ac.uk/3499/1/3499.pdf.

Salingaros, N.A., 1998. Theory of the urban web. *Journal of Urban Design*, 3(1), pp.53–71.

Salingaros, N.A., 2000. Complexity and urban coherence. *Journal of Urban Design*, 5(3), pp.291–316.

Scott, J., 2000. *Social network analysis: a handbook. 2000*, Sage Publications, London.

Scruton, R., 1979. The Aesthetics of Architecture (London: , 1979). In *quoted in Frank Sibley, Approach to Aesthetics: Collected Papers on Philosophical Aesthetics*. London: Methuen, p. 9.

Seamon, D., 1993. *Dwelling, seeing, and designing: Toward a phenomenological ecology*, State Univ of New York Pr.

Seamon, D., 2004. Grasping the dynamism of urban place: Contributions from the work of Christopher Alexander, Bill Hillier, and Daniel Kemmis. *Reanimating Places, Ashgate, Burlington, Vermont*, pp.123–45. Available at: http://ksu.academia.edu/documents/0058/6538/Seamon_Buttimer_Animating_Places_04.pdf.

Seamon, D., 2007. A lived hermetic of people and place: Phenomenology and space syntax. In *6th International Space Syntax Symposium*. 6th International Space Syntax Symposium. Istanbul, Turkey, p. iviv12. Available at: http://krex.k-state.edu/dspace/bitstream/2097/1689/1/SeamonISSS6.pdf.

Seamon, D., 2007. Interconnections, Relationships, & Dwelling as Wholeness: A Phenomenological Ecology of Natural & Humanmade Worlds. Available at: http://smartech.gatech.edu/bitstream/1853/16866/5/presentation.pdf.txt.

Seamon, D., 2008. Phenomenology, place, environment, and architecture: A review. *Environmental & architectural phenomenology newsletter*. Available at: http://ksu.academia.edu/DavidSeamon/Papers.

Seamon, D., Understanding and Making Places in the City: Integrating the Urban Visions of Christopher Alexander and Bill Hillier. Available at: http://www.idrp.wsu.edu/Vol_2/Seamon.pdf.

Seamon, D., 2008. Understanding and Making Places in the City: Integrating the Urban Visions of Christopher Alexander and Bill Hillier. *Interdisciplinary Design and Research e-Journal*, 2. Available at: http://www.idrp.wsu.edu/.

Seamon, D. & Mugerauer, R., 1985. *Dwelling, place, and environment: towards a phenomenology of person and world*, Kluwer Academic Pub.

Seamon, D. & Nordin, C., 1980. Marketplace as place ballet. *Landscape*, 24(3), pp.35–41. Available at: http://ksu.academia.edu/documents/0095/7512/Seamon___Nordin_Varberg_Market_LANDSCAPE_1980.pdf.

Shannon, C.E. & Weaver, W., 1949. The mathematical theory of information. *Urbana: University of Illinois Press*, 97.

Society, B.H.S.B., 2006. History - Brentham Garden Suburb. Available at: http://www.brentham.com/html/history.html [Accessed January 16, 2011].

Stamps, A.E., 2000. *Psychology and the aesthetics of the built environment*, Springer Netherlands.

Stamps, A.E., 2003. Advances in visual diversity and entropy. *Environment and Planning B*, 30(3), pp.449–464.

Stamps, A.E. & others, 2004. Mystery, complexity, legibility and coherence: A meta-analysis. *Journal of Environmental Psychology*, 24(1), pp.1–16.

Steadman, P., 1983. *Architectural morphology: an introduction to the geometry of building plans*, Pion Ltd.

Stein, C. & Mumford, L., 1951. *Introduction to Towards New Towns for America*, Chicago: The University Press Of Liverpool.

Survey, O., 2010. Maps of Britain from Ordnance Survey - buy paper maps and GIS data. Available at: http://www.ordnancesurvey.co.uk/oswebsite/ [Accessed January 16, 2011].

Talen, E., 1999. Sense of community and neighbourhood form: an assessment of the social doctrine of new urbanism. *Urban Studies*, 36(8), p.1361.

Talen, E., 2000. The problem with community in planning. *Journal of Planning Literature*, 15(2), p.171.

Tandy, C.R.V., 1967. The isovist method of landscape survey. In *Symposium on Methods of Landscape Analysis*. pp. 9–10.

Taylor, R.B., Gottfredson, S.D. & Brower, S., 1981. Territorial cognitions and social climate in urban neighborhoods. *Basic and Applied Social Psychology*, 2(4), pp.289–303.

Taylor, R.B., Gottfredson, S.D. & Brower, S., 1984. Neighborhood naming as an index of attachment to place. *Population & Environment*, 7(2), pp.103–125.

Teklenburg, J.A., Timmermans, H.J.P. & Van Wagenberg, A.F., 1993. Space syntax: standardised integration measures and some simulations. *Environment and Planning B*, 20, pp.347–347.

Tschumi, B., 1996. *Architecture and disjunction*, the MIT Press.

Tuan, Y.F., 1977. Space and Place: the perspective of experience (Minneapolis, MN, University of Minnesota Press).

Tuan, Y.F., 1974. *Topophilia: a study of environmental perception, attitudes, and values*, Prentice-Hall.

Tuan, Y.F., 1974. Space and place: humanistic perspective. *Progress in Human Geography*, 6, pp.233–46.

Tuan, Y.F., 2001. *Space and place: The perspective of experience*, Univ Of Minnesota Press.

Turner, A., 2001. Angular analysis. In *Proceedings of the 3rd International Symposium on Space Syntax*. pp. 30–1. Available at: http://www.vr.ucl.ac.uk/people/alasdair/publications/angular.pdf.

Turner, A. et al., 2001. From isovists to visibility graphs: a methodology for the analysis of architectural space. *Environment and Planning B*, 28(1), pp.103–122.

Turner, A., 2003. Analysing the visual dynamics of spatial morphology. *Environment and Planning B*, 30(5), pp.657–676. Available at: http://eprints.ucl.ac.uk/archive/00000154/01/Turner_2003_spatialmorphology.pdf.

Turner, A. & Dalton, N., 2005. A simplified route choice model using the shortest angular path assumption. Paper presented at the 8th International Conference on GeoCompuation, Ann Arbor, Michigan, USA.

Turner, A. & Penn, A., 1999. Making isovists syntactic: isovist integration analysis. In *2nd International Symposium on Space Syntax, Brasilia*.

Warren, D.I., 1975. *Black neighborhoods: An assessment of community power*, University of Michigan press.

Warren, R. L. 1965. *Studying your community.* The Free Press.

Watts, D.J. & Strogatz, S.H., 1998. Collective dynamics of 'small-world'networks. *Nature*, 393(6684), pp.440–442.

Webber, M., 1963. Order in diversity: community without propinquity. In Lowdon Wingo, J., ed. *Cities and space: the future use of urban land.* Johns Hopkins Press, Baltimore MD.

Webster, C., 2003. The nature of the neighbourhood. *Urban Studies*, 40(13), pp.2591–2612.

Wilkinson, D.M. & Huberman, B.A., 2004. A method for finding communities of related genes. *Proceedings of the National Academy of Sciences of the United States of America*, 101(Suppl 1), p.5241.

Willmott, P., and D. Thomas. 1984. *Community in social policy.* Policy Studies Institute.

Withington, P., 2006. Areas of Beacon Hill. Private communication to N.Dalton

Wu, F. & Huberman, B.A., 2004. Finding communities in linear time: a physics approach. *The European Physical Journal B-Condensed Matter and Complex Systems*, 38(2), pp.331–338.

Yang, T., 2006. The role of space in the emergence of conceived urban areas. In *Spatial Cognition '06*. Space Syntax and Spatial Cognition Workshop Proceedings. Universität Bremen Germany.

Yang, T. & B. Hillier. 2007. The fuzzy boundary: the spatial definition of urban areas. In *Proceedings 6th international space syntax symposium. Istanbul, Turkey*, ed. A.S. Kubat, Ö Ertekin, and Y.Io. Güney, 091.01-22. Cenkler, Istanbul: Istanbul Technical University.

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